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Russell

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(54) **SEAMLESS MULTISTAGE HANDOFF ALGORITHM TO FACILITATE HANDOFFS BETWEEN HETEROGENEOUS WIRELESS NETWORKS**

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(60) Provisional application No. 60/382,705, filed on May 21, 2002.

(51) **Int. Cl.**
H04M 1/00 (2006.01)

(52) **U.S. Cl.** **455/552.1**; 455/436; 455/440; 455/414.1; 455/418; 455/441; 455/550.1; 370/328; 370/338

(58) **Field of Classification Search** 455/432.1-453; 370/328-338

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,864,494	A *	9/1989	Kobus, Jr.	726/33
5,301,359	A *	4/1994	Van den Heuvel et al. ...	455/524
5,519,778	A *	5/1996	Leighton et al.	380/30
5,625,877	A *	4/1997	Dunn et al.	455/454
5,818,814	A *	10/1998	Testani et al.	370/212
5,878,344	A *	3/1999	Zicker	455/426.1
5,901,352	A *	5/1999	St-Pierre et al.	455/426.1
6,591,103	B1 *	7/2003	Dunn et al.	455/436
6,804,532	B1 *	10/2004	Moon et al.	455/552.1
7,072,657	B2 *	7/2006	Watanabe et al.	455/439
2004/0192309	A1 *	9/2004	Watanabe et al.	455/439
2004/0203998	A1 *	10/2004	Knauerhase et al.	455/550.1
2006/0111084	A1 *	5/2006	Adatrao et al.	455/412.1
2007/0149133	A1 *	6/2007	Lee	455/67.11
2007/0249316	A1 *	10/2007	Rao	455/343.1

* cited by examiner

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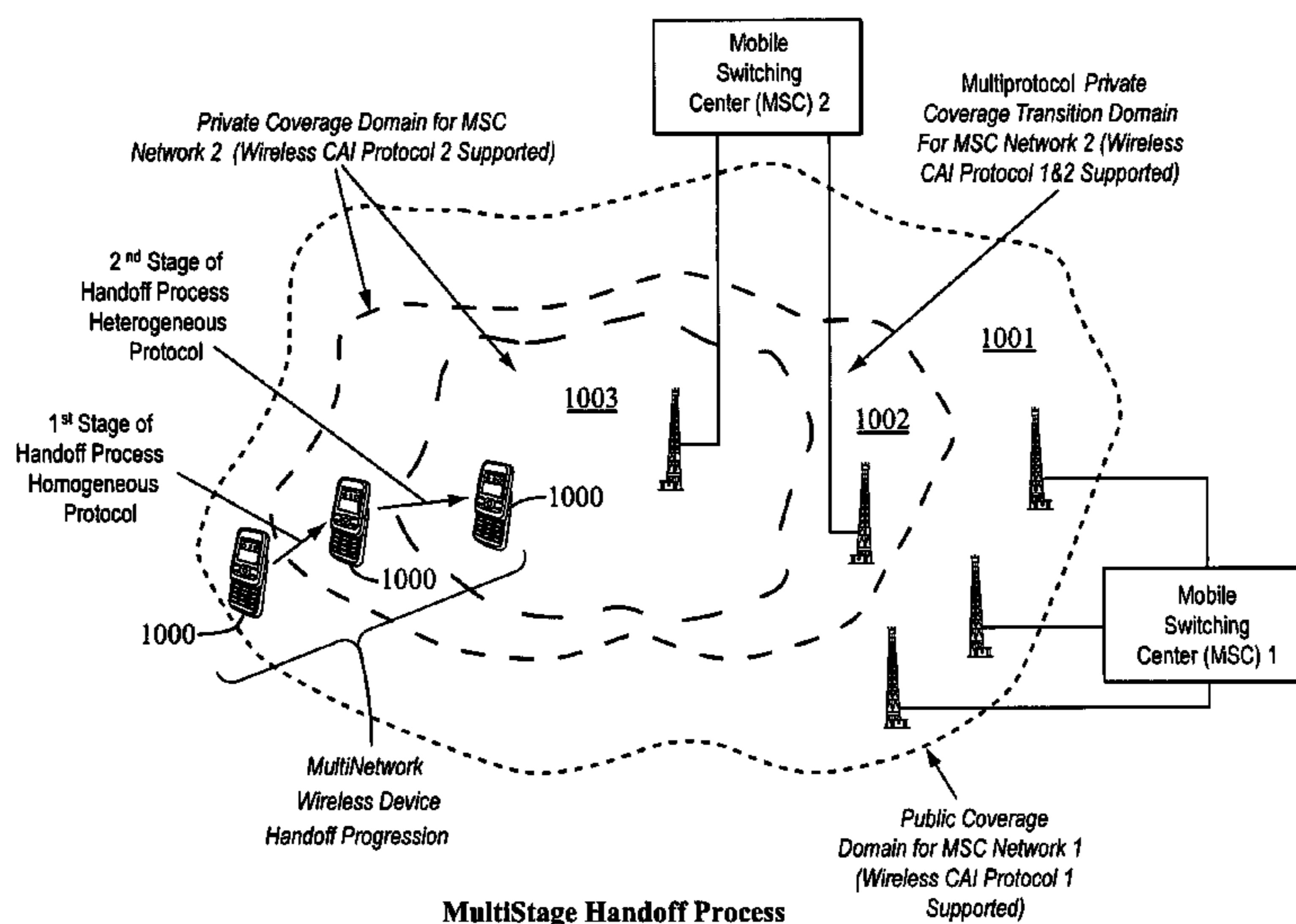
Assistant Examiner — Babar Sarwar

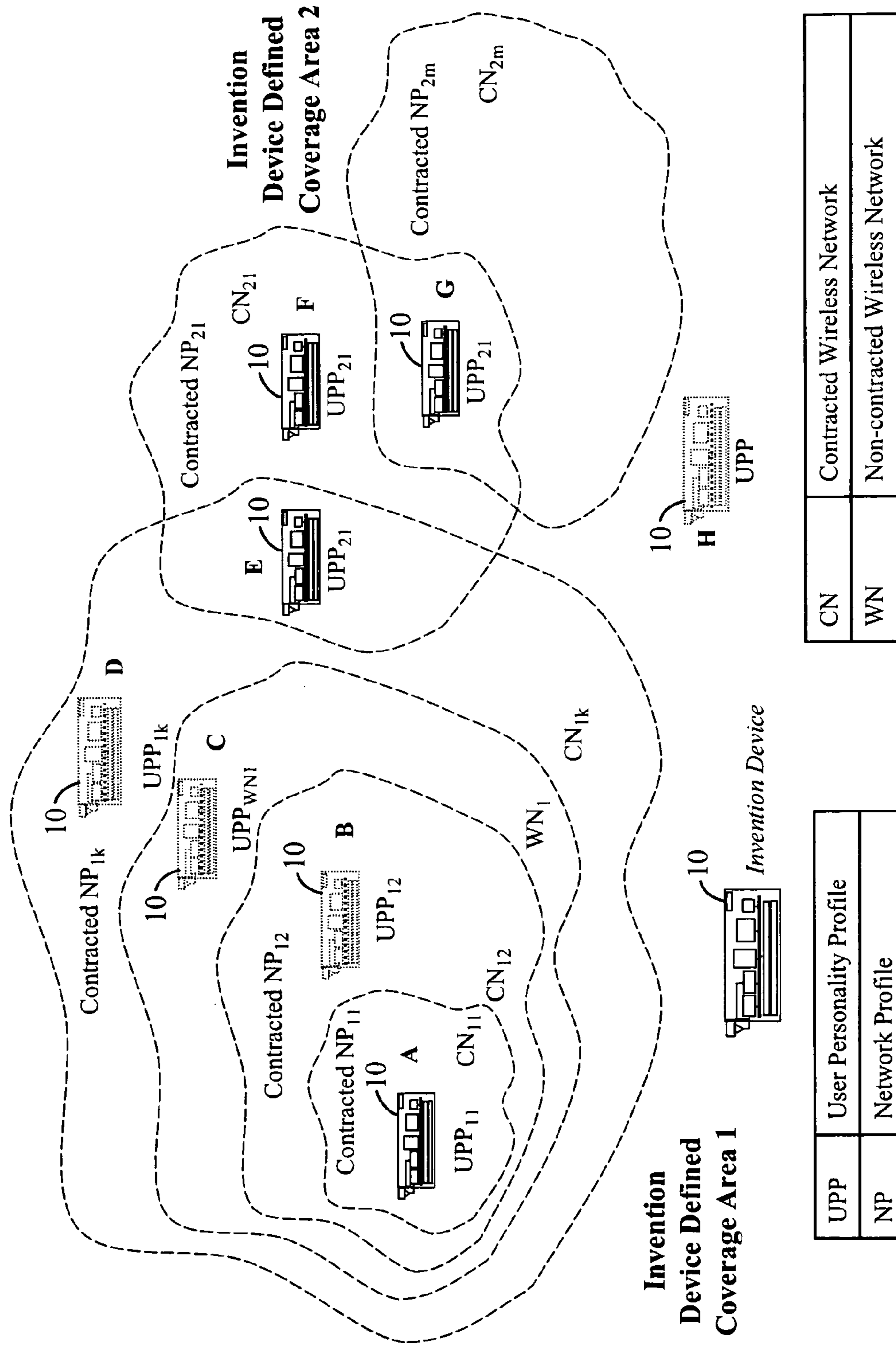
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(57) **ABSTRACT**

A method for automatically adapting a multi-protocol wireless device to facilitate a seamless multistage handoff according to various embodiments can include initiating a seamless multistage handoff process using a multi-protocol wireless device when the multi-protocol wireless device crosses a boundary area into an overlapping region where the multi-protocol wireless device is capable of simultaneously accessing a plurality of networks; and implementing the seamless multistage handoff process by performing at least a two-stage handoff process comprising a homogeneous handoff and a heterogeneous handoff without interrupting a communication call session conducted using the multi-protocol wireless device. A multi-network client device according to various embodiments can include a controller configured to support multiple independent call sessions, wherein the independent call sessions are concurrently conducted on a single wireless device through the use of parallel communication sessions and simultaneously connect the wireless device to a plurality of different networks hosting different content services.

47 Claims, 16 Drawing Sheets

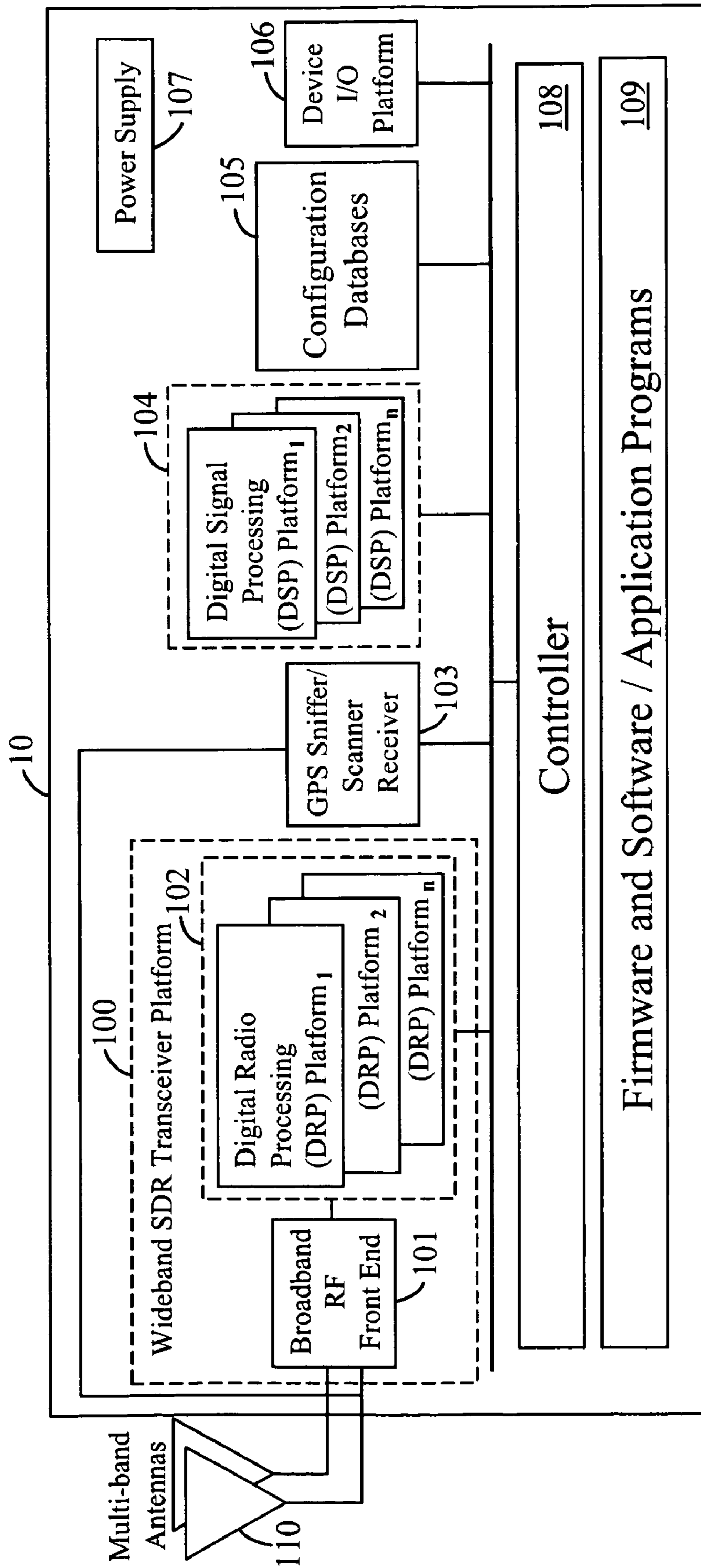




Network Detection and Access
Figure 1

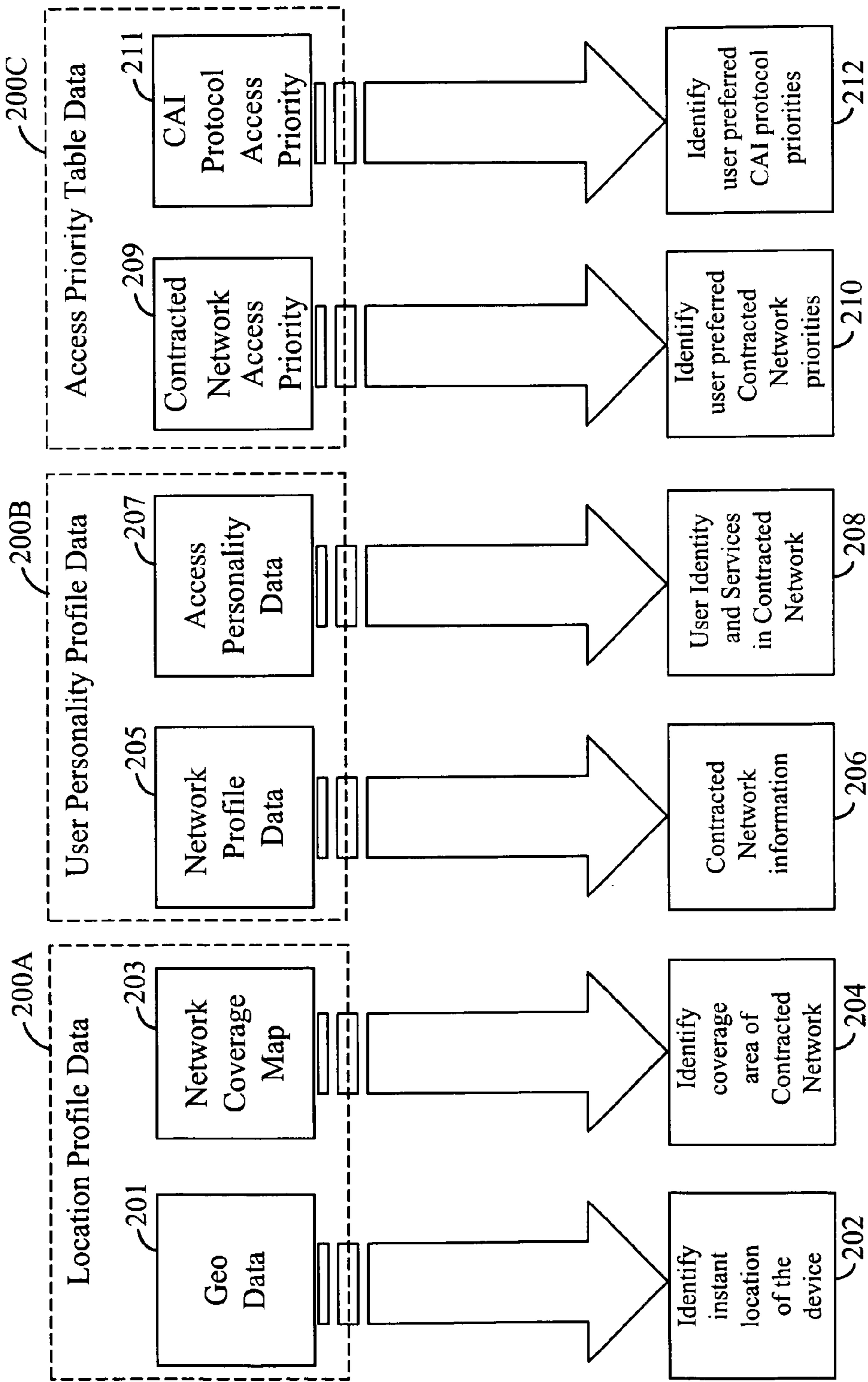
CN	Contracted Wireless Network
WN	Non-contracted Wireless Network

UPP	User Personality Profile
NP	Network Profile



INVENTION DEVICE ARCHITECTURE

Figure 2A



Position and Protocol Assisted Learning (P²AL) Algorithm Database Structure
Figure 2B

NCM Data File	
CN	NCM
1	boundary points
2	boundary points
3	boundary points
...	boundary points
k	boundary points

Figure 2C

UPP Data File	
CN	AP NP
1	AP1 NP1
2	AP2 NP2
3	AP3 NP3
...	APj NPj
k	APk NPk

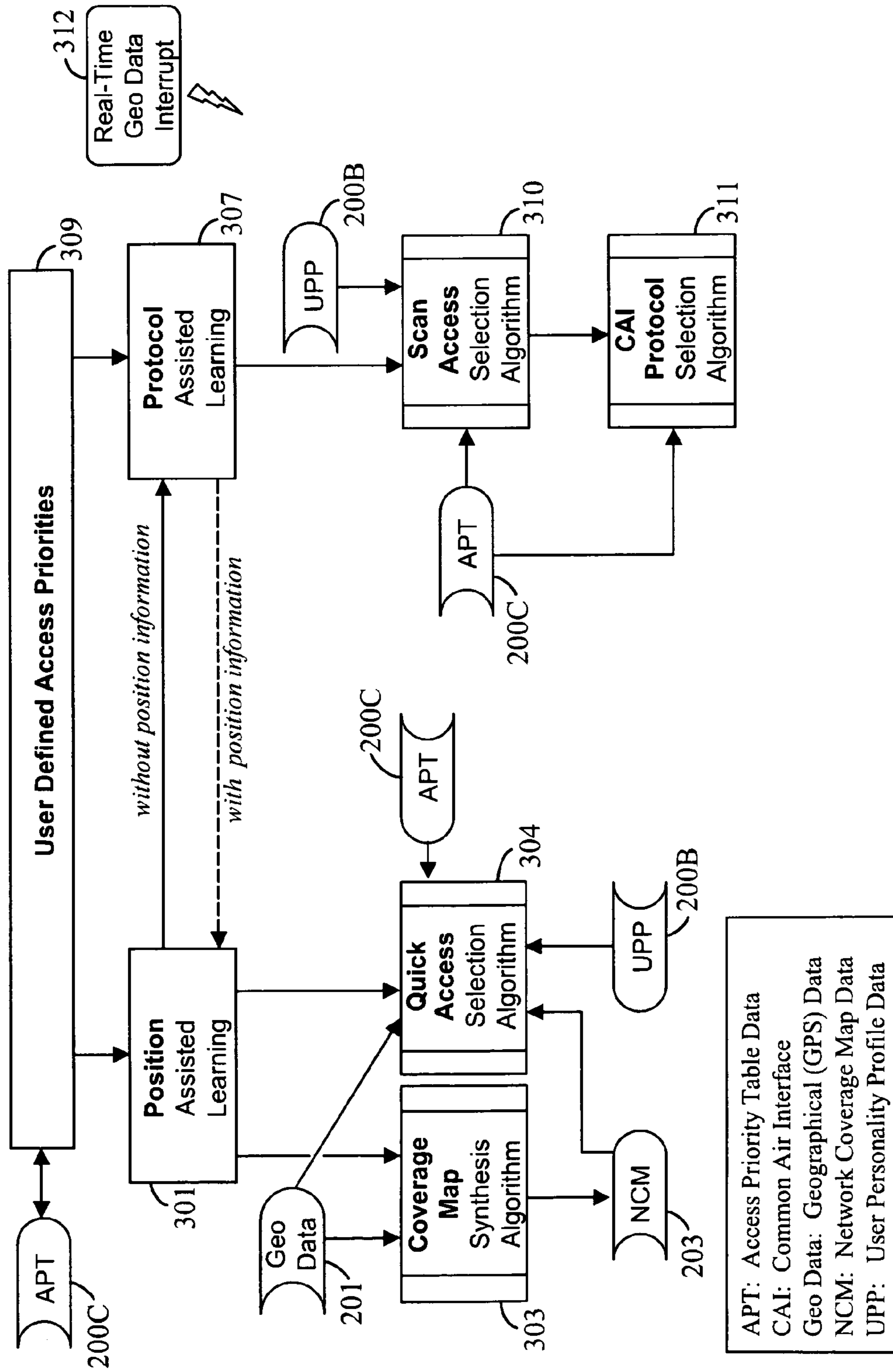
Figure 2D

APT: Access Priority Table
 UPP: User Personality Profile
 NCM: Network Coverage Map
 CN: Contracted Network
 AP: Access Personality
 NP: Network Profile
 CAI: Common Air Interface (CAI)

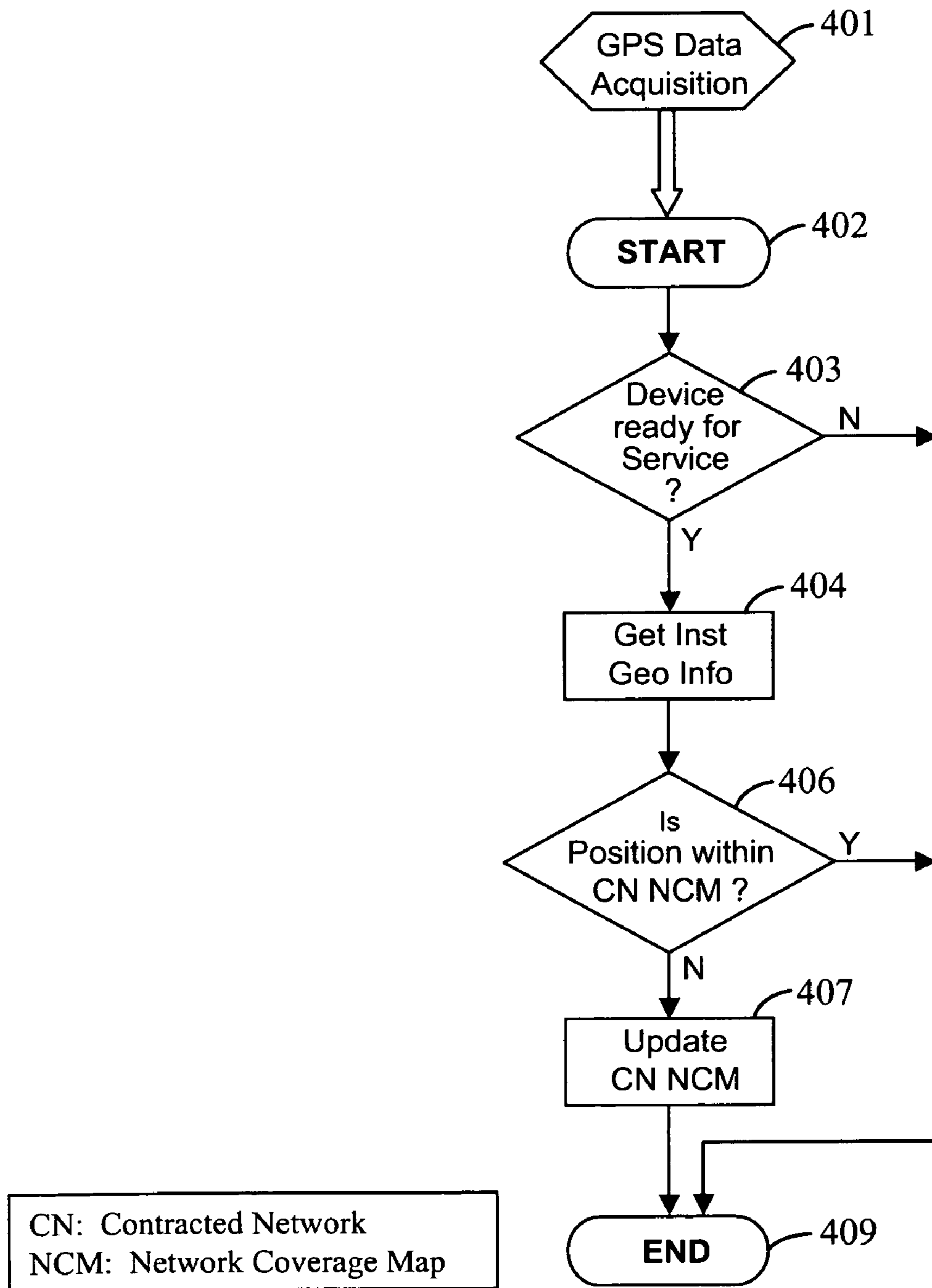
APT Data File	
Priority	CN CAI
1	CN1 CAI1
2	CN3 CAI3
3	CNj CAI2
4	CNk ...
...	CAIx
k	CN2

Figure 2E

NCM, UPP and APT Databases

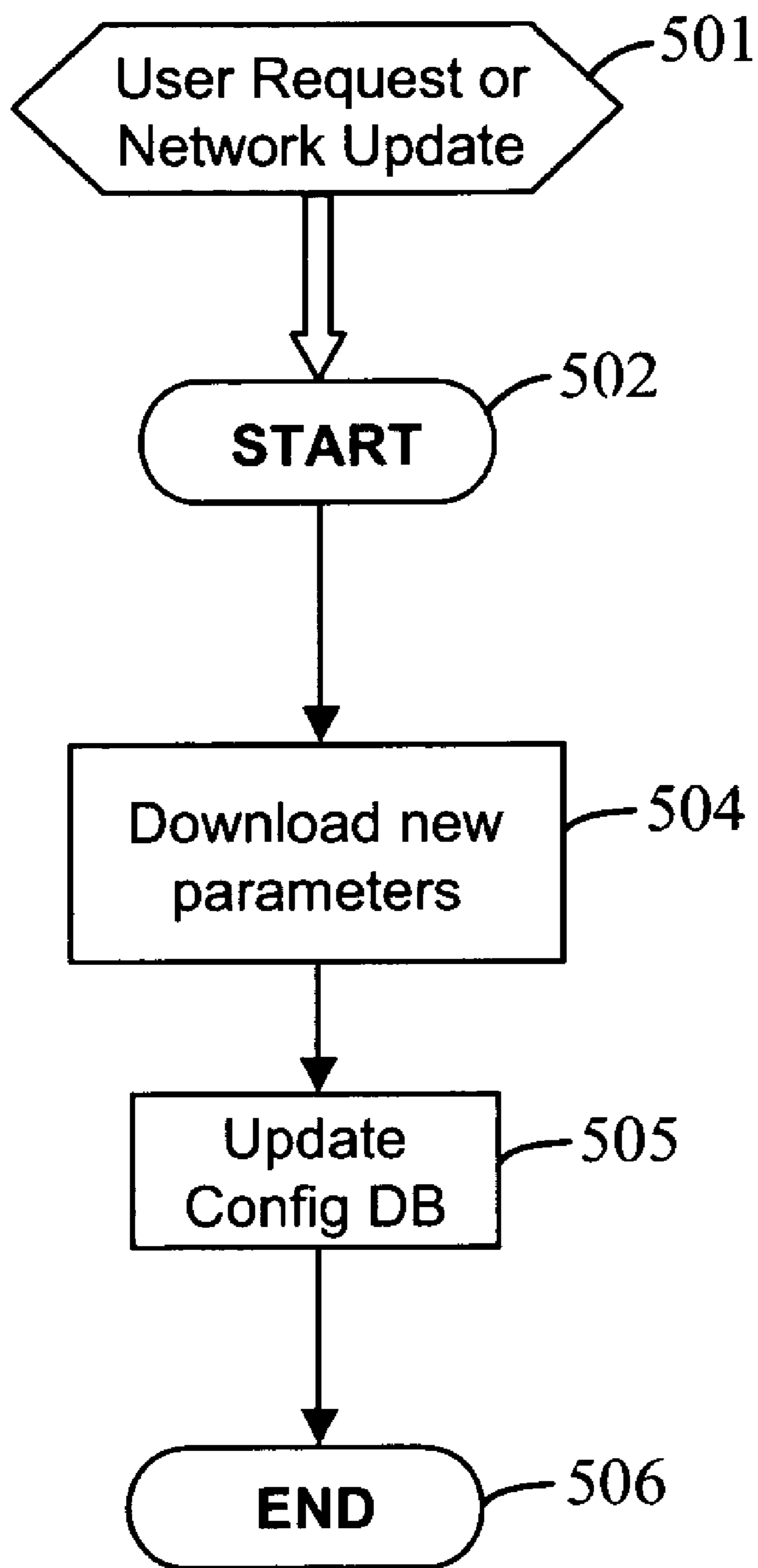


Position and Protocol Assisted Learning (P²AL) Algorithm
Figure 3



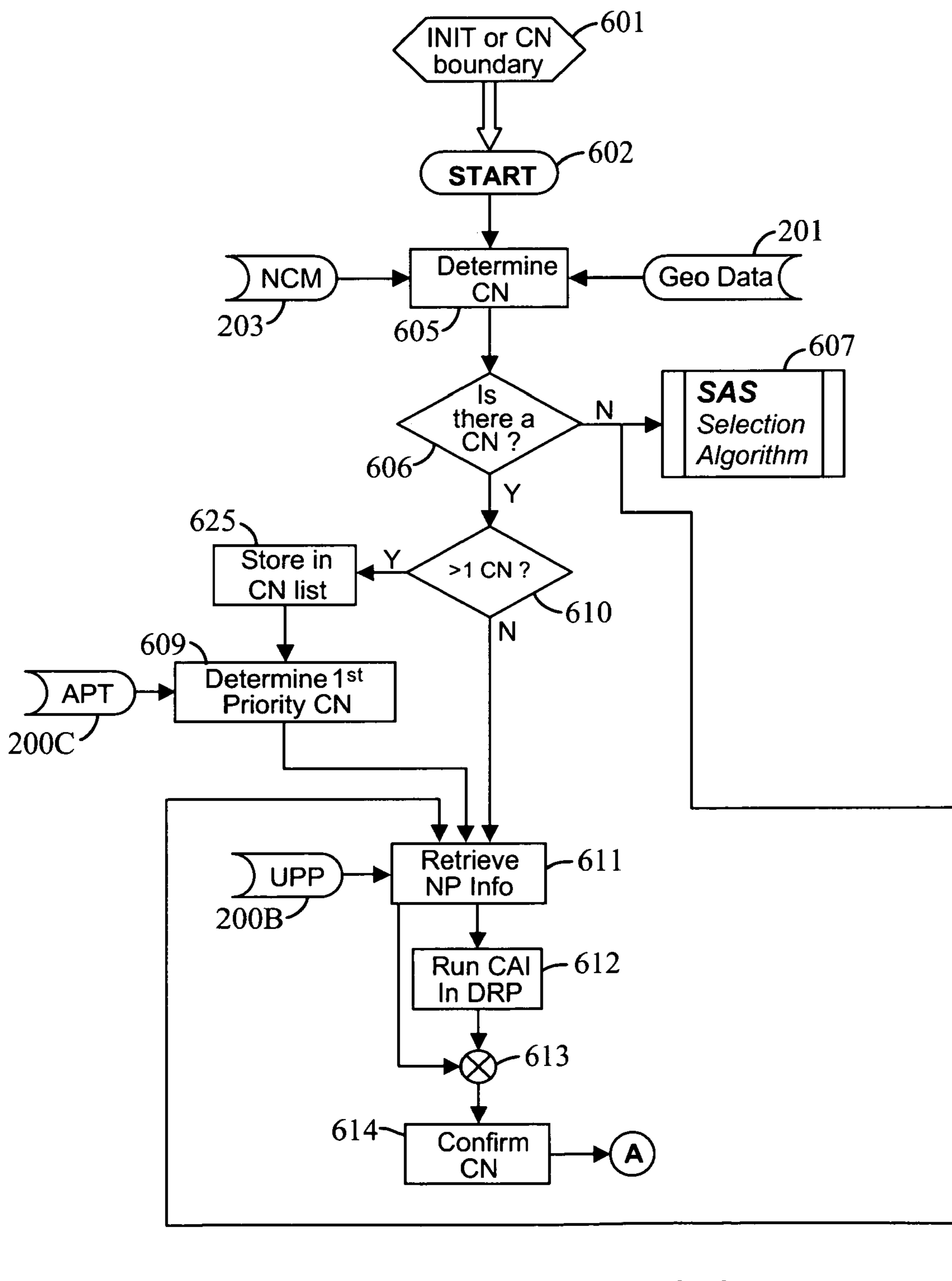
**Coverage Map Synthesis (CMS)
 Algorithm Portion of the P²AL Algorithm**

Figure 4



Capability Update Algorithm

Figure 5



**Quick Access Selection (QAS)
Algorithm Portion of the P²AL Algorithm
Figure 6 (PART 1)**

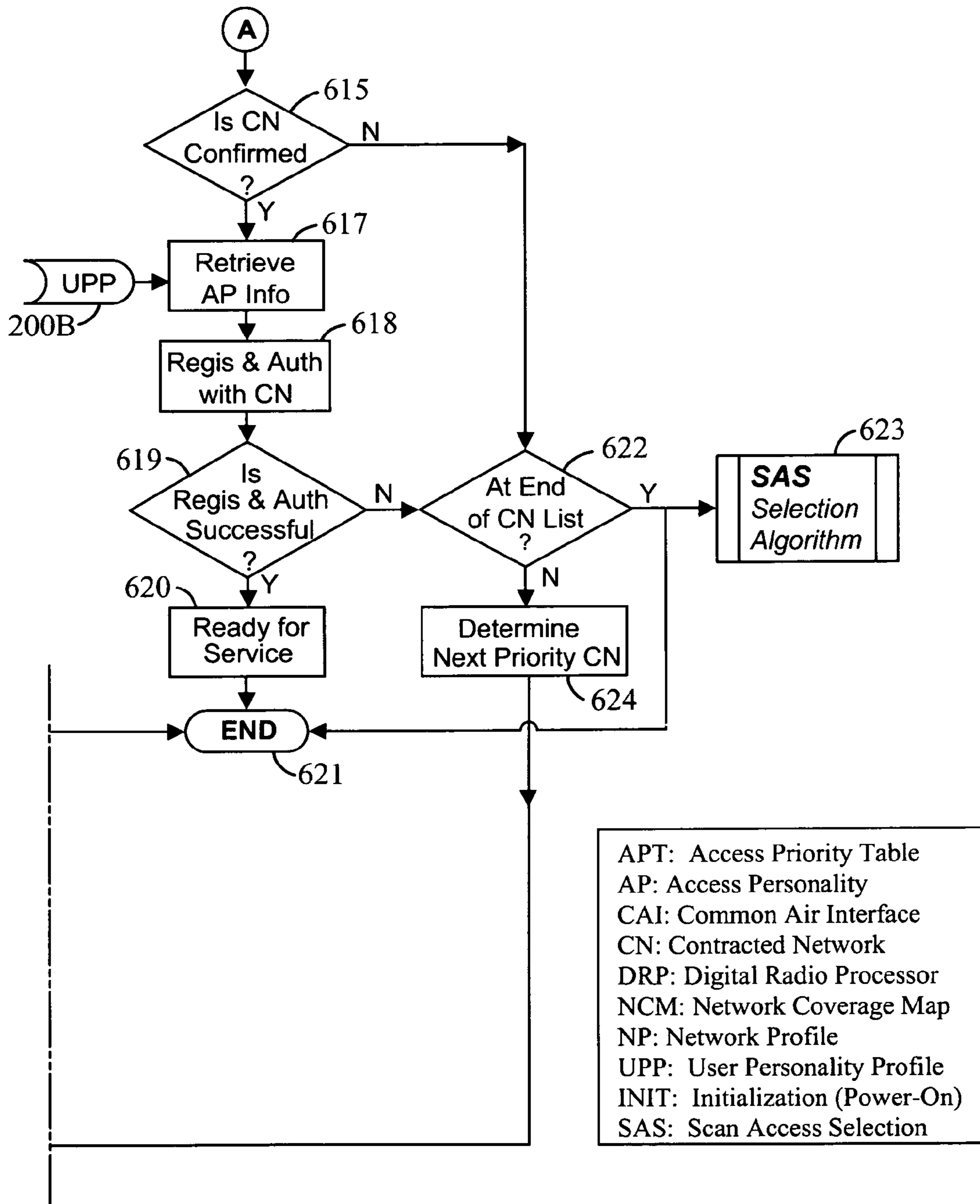
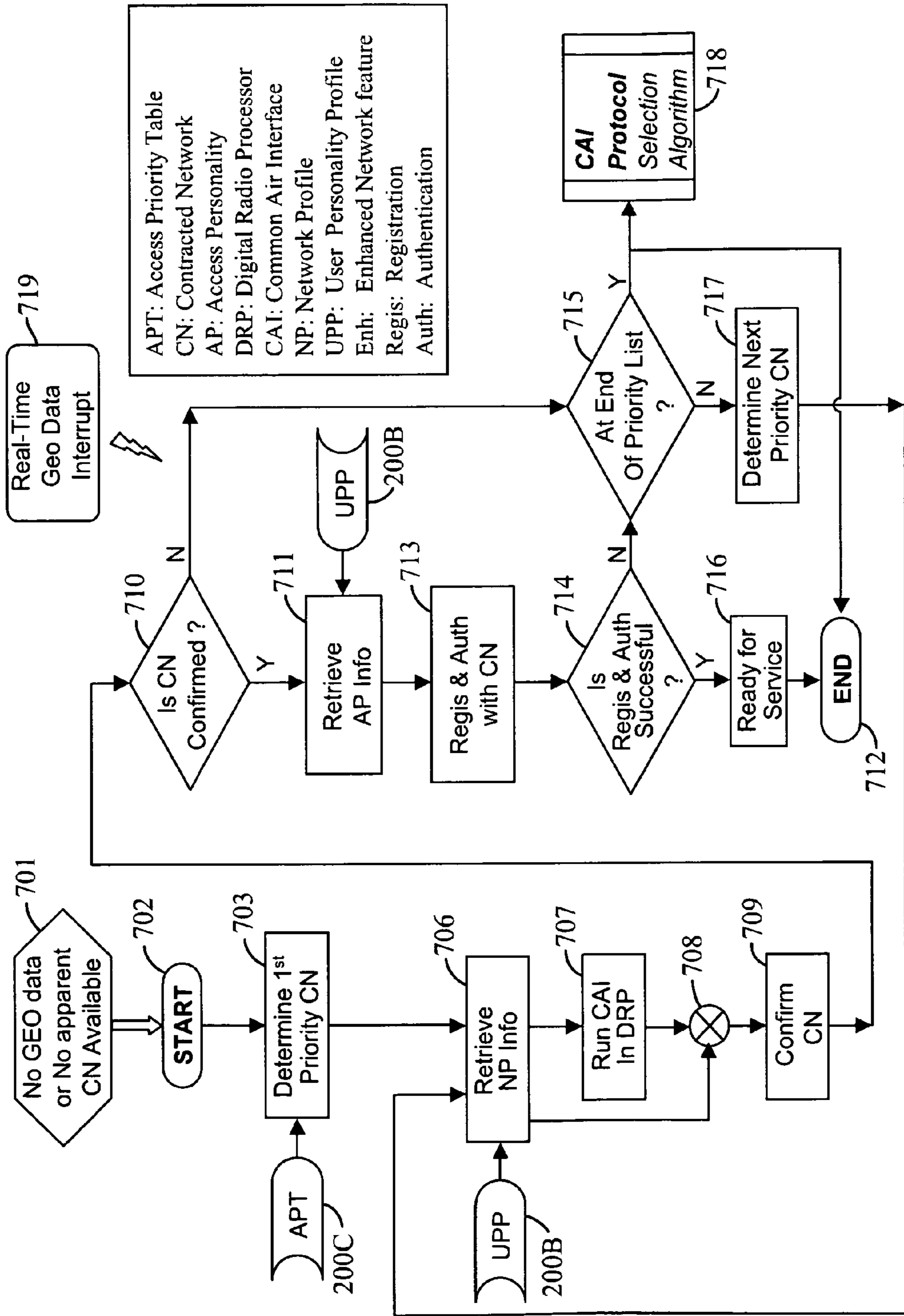
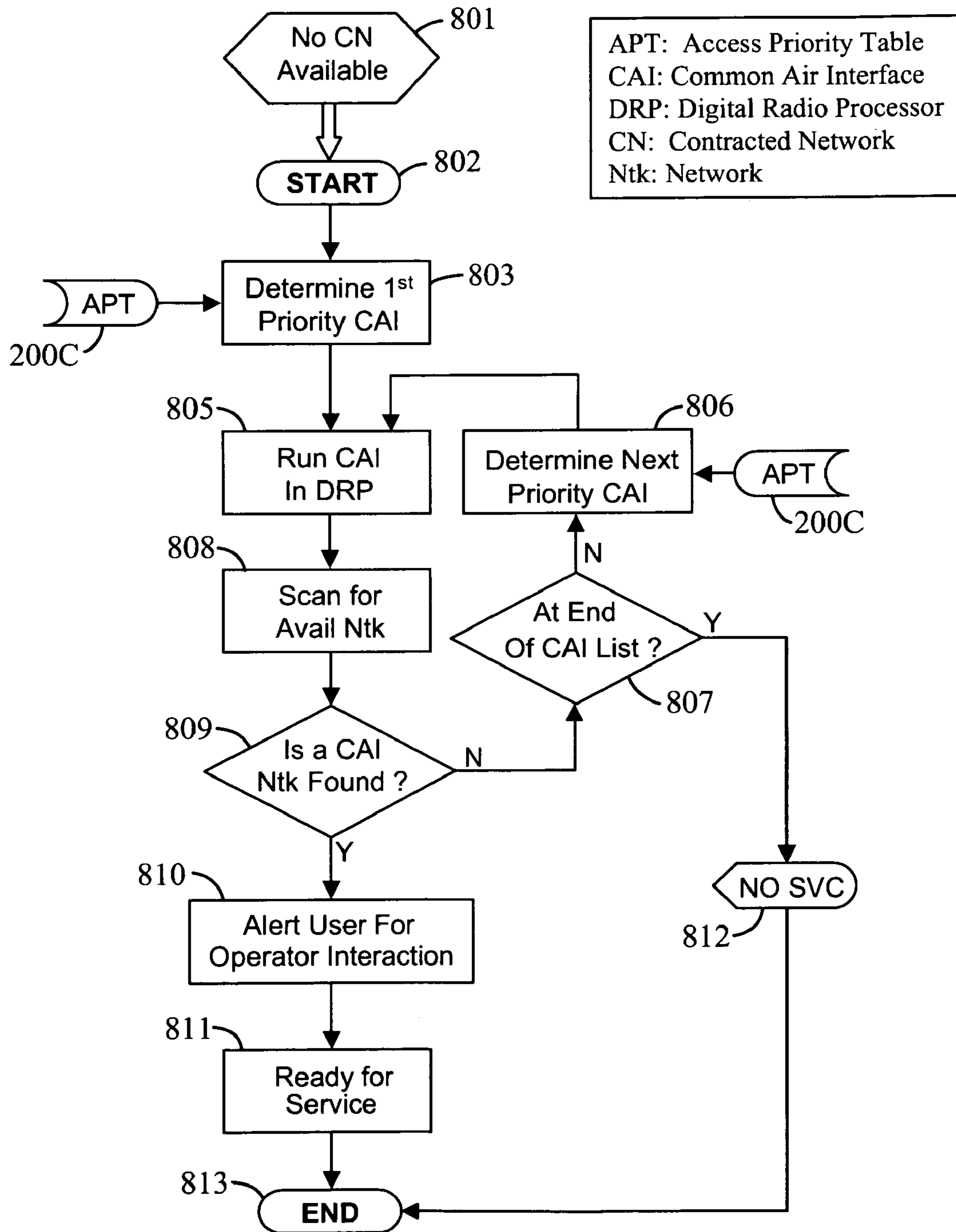


Figure 6 (PART 2)

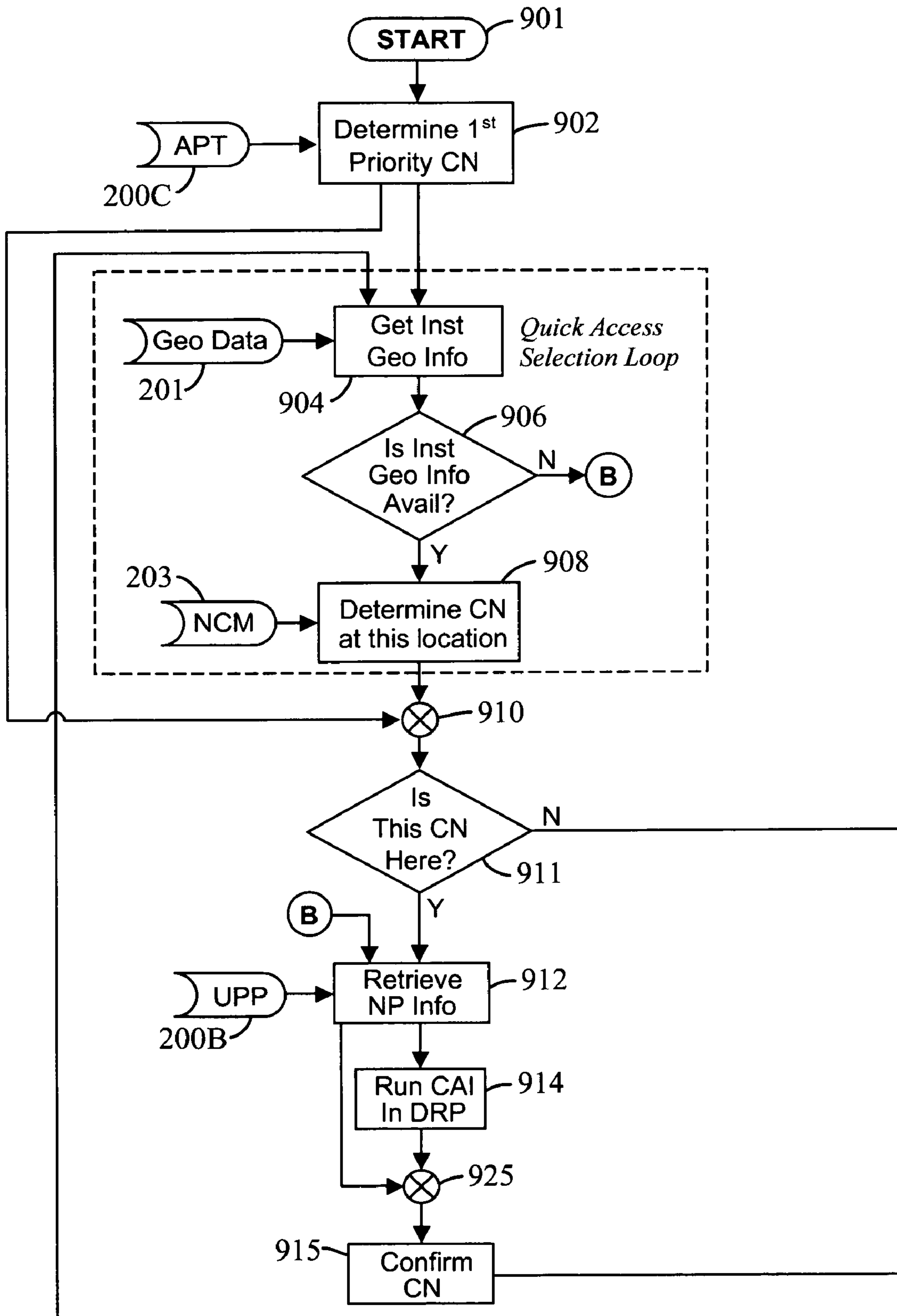


Scan Access Selection (SAS) Algorithm Portion of the P2AL Algorithm

Figure 7



**CAI Protocol Selection Algorithm Portion
 of the P²AL Algorithm
 Figure 8**



Priority-Driven Access Selection Algorithm

Figure 9 (PART 1)

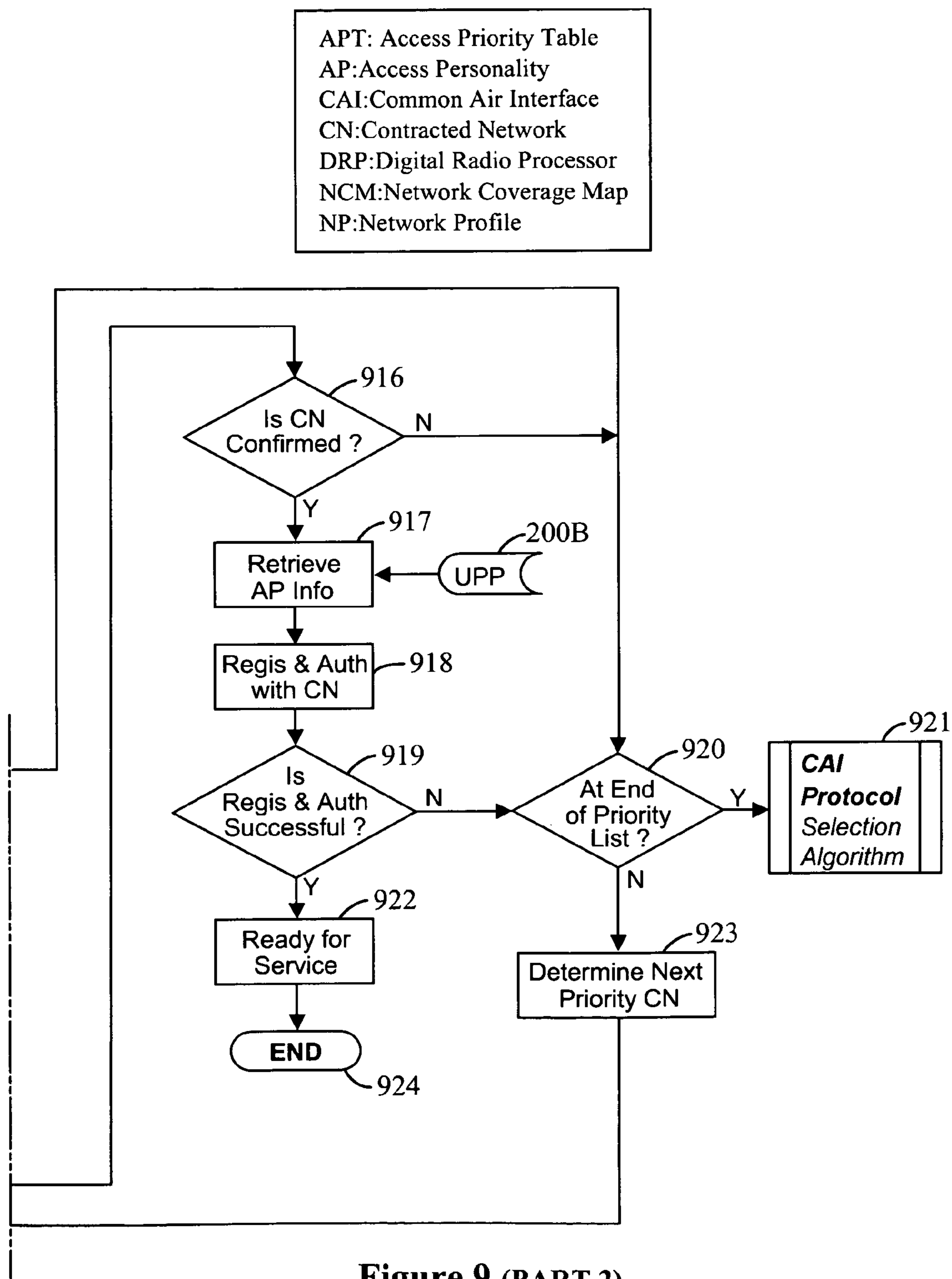
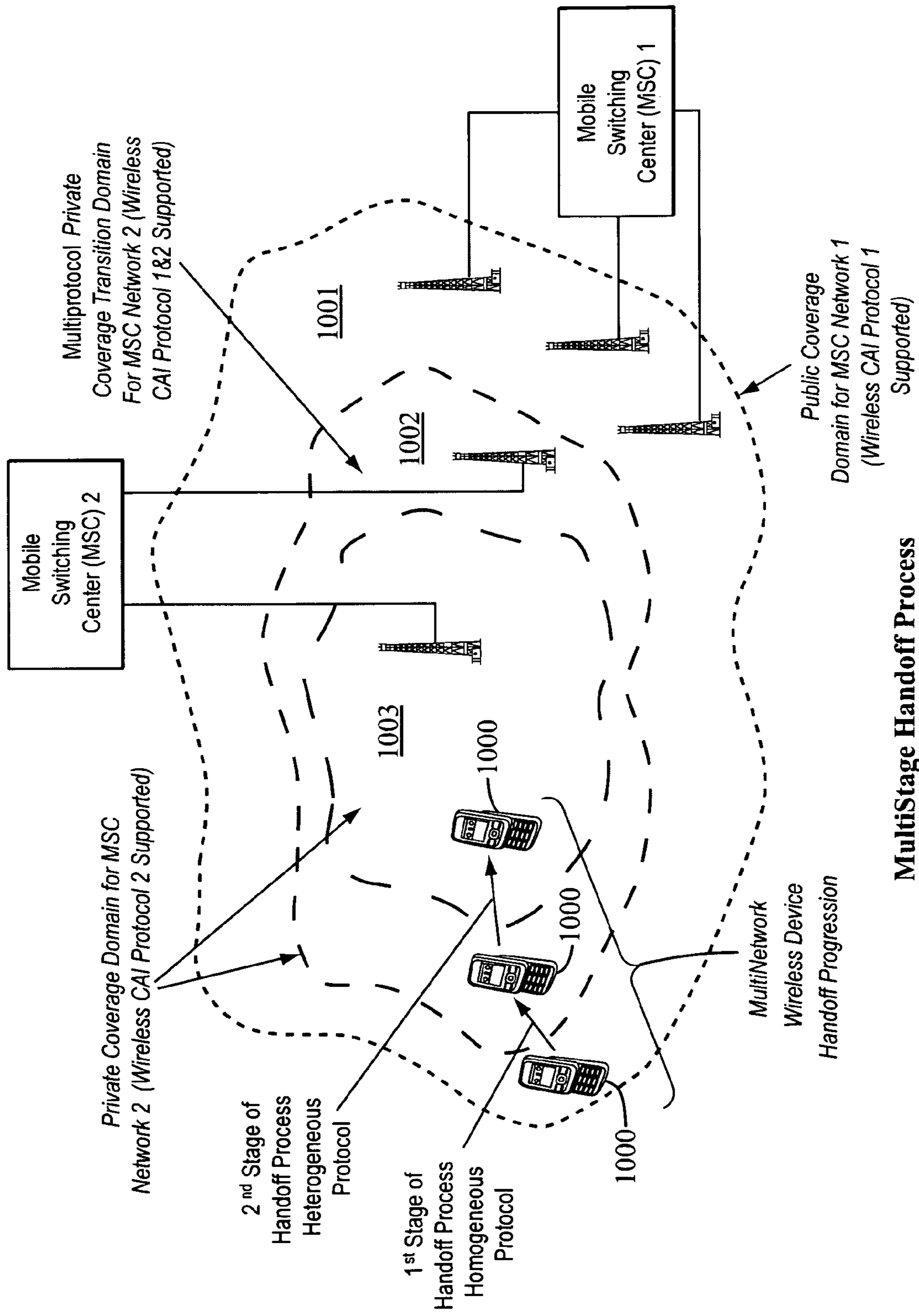


Figure 9 (PART 2)



MultiStage Handoff Process

Figure 10

MultiStage Heterogeneous Handoff Call-Flow
Figure 11A

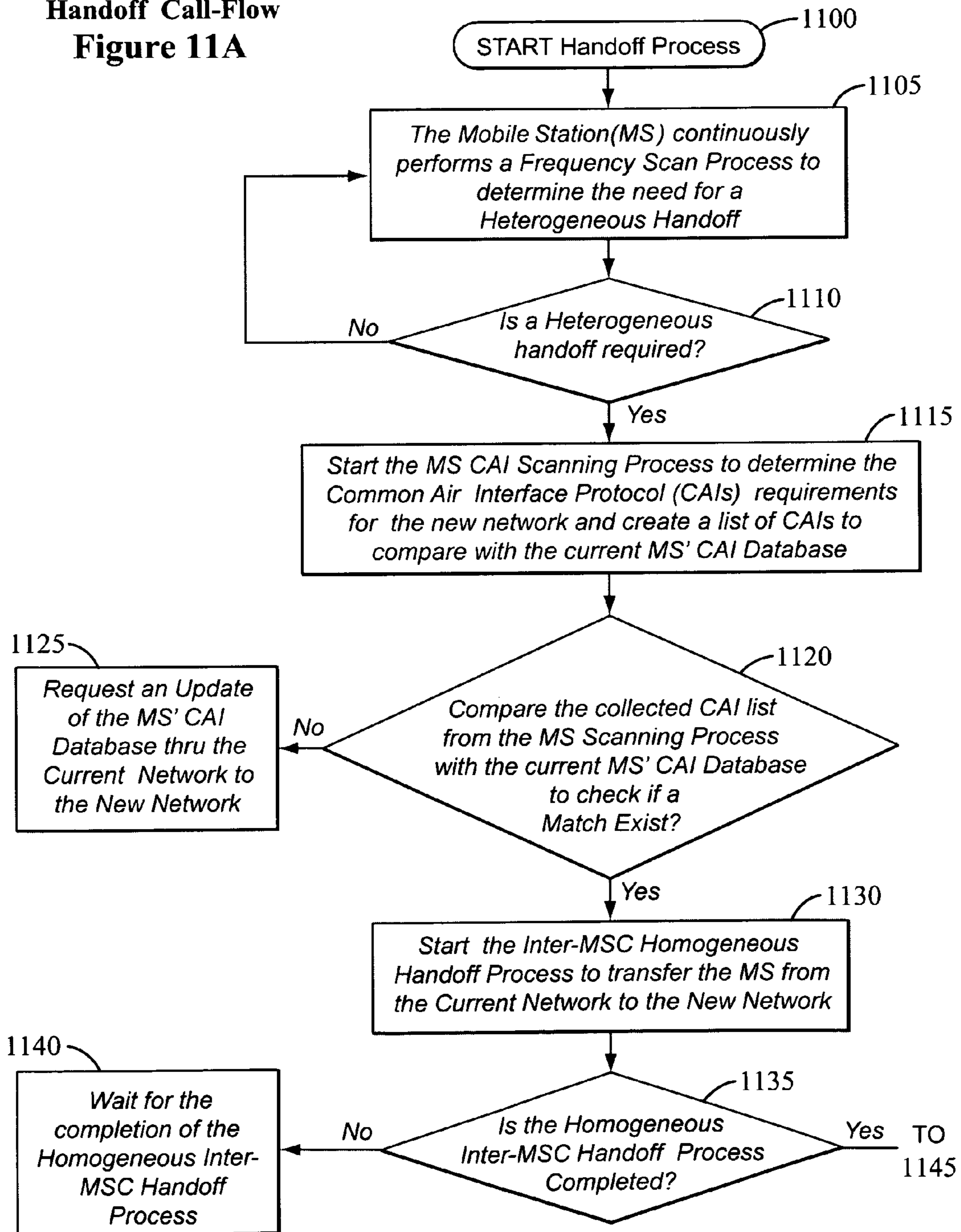
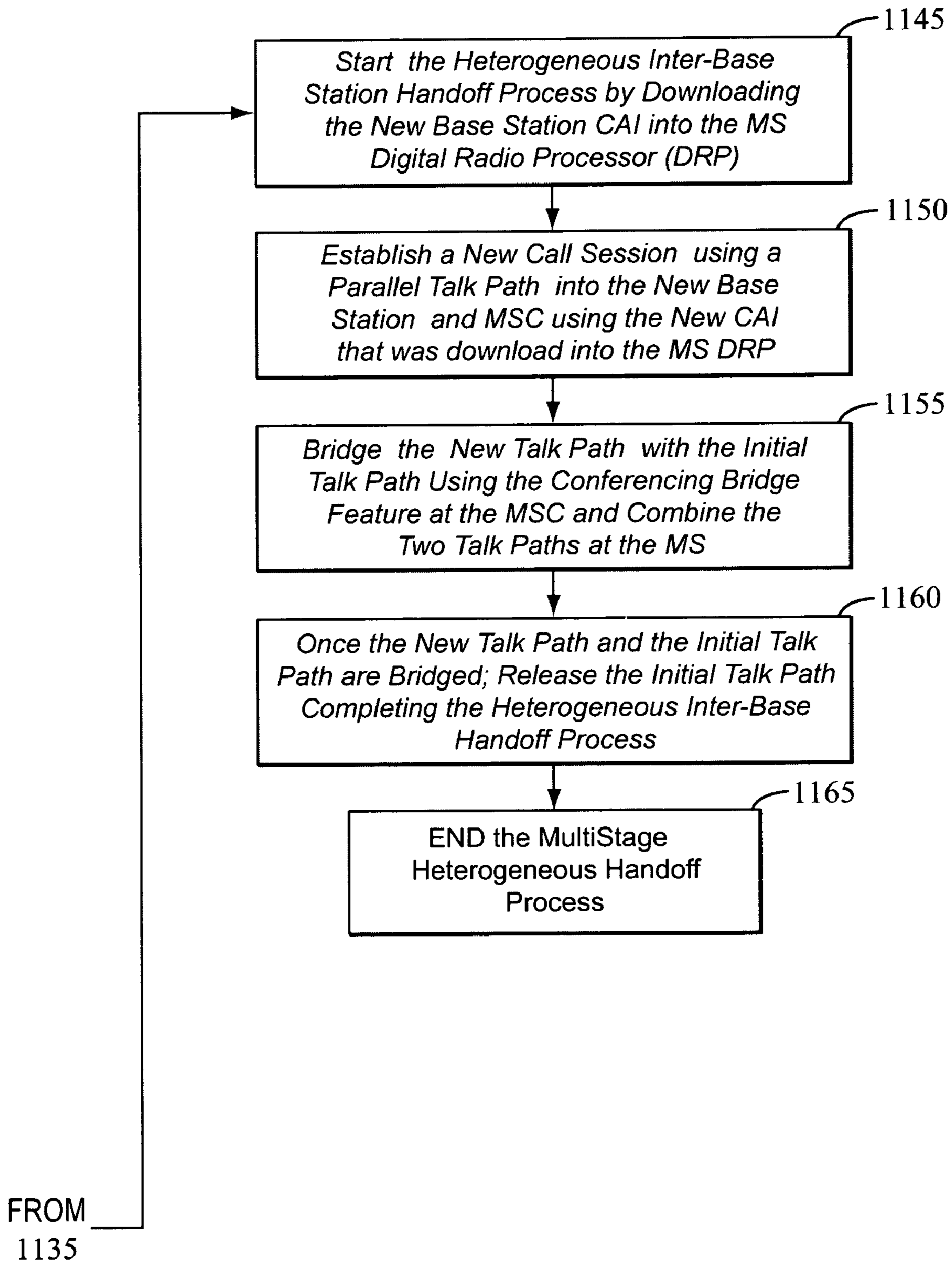


Figure 11B



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**SEAMLESS MULTISTAGE HANDOFF
ALGORITHM TO FACILITATE HANDOFFS
BETWEEN HETEROGENEOUS WIRELESS
NETWORKS**

RELATED APPLICATIONS

This application is a Continuation-in-Part of copending U.S. patent application Ser. Nos. 12/081,139 and 12/081,140, both filed Apr. 10, 2008, which are Divisional Applications of U.S. patent application Ser. No. 10/443,128, filed on May 20, 2003 now U.S. Pat. No. 7,437,158, and claims priority of Provisional Application No. 60/382,705, filed on May 21, 2002. The entire disclosures of these applications are expressly incorporated herein by reference.

DESCRIPTION OF THE INVENTION

1. Field of the Invention

The present teachings relate to methods and devices for facilitating a seamless multistage handoff between heterogeneous wireless systems and networks.

2. Background of the Invention

I: The convergence of telecommunications, multimedia and wireless technologies creates the demand for robust, modular, and wideband devices which serve the needs of users (especially business users) for extended (ubiquitous) wireless access across several geographic “campuses”, ease of access to any wireless network, consistent look and feel across networks, and broadband access to new services. As more wireless devices access the Internet than PCs, users will demand more functionality and capability from those devices.

An End User Device, “EUD” (e.g. Mobile Station (MS) or Handset) provides user access to any wireless (e.g. cellular or wireless LANs) communications network. This takes the form of voice, data/internet access, and multimedia. Access to the wireless network’s full features and services is limited by the capabilities of the end user device. As today’s systems become more complex and integrated, the EUD is a critical component to unlocking network functionality and providing seamless, streamlined, and effortless access to emerging wireless services.

Current networks often require new devices for each technology in disparate wireless (e.g. cellular) networks. Recent implementations of EUDs have given way to re-configurable devices which change their profiles through the use of programmable radios and multiband antennas. A Software Defined Radio (SDR) is specified in the industry as a radio providing multiple modulation techniques and frequency ranges in narrow or wide-band operation under software control. The radios can adapt to multiple networks and are “configurable” (software configurable) to one Common Air Interface (CAI) protocol at a time. Historically, this approach has been used for military applications and was expensive on a per-subscriber basis. Power constraints in the handset (end user device) often limited the technology to Base Station (BS) or Access Point (AP) applications. Recent technology advances have made this a viable approach for today’s wireless devices.

SDRs generally integrate the “inner” and “outer” communications functions into a single chipset which forms so-called “single-chip radios” or “single-chip devices”. These devices function from a single point of program control. The “outer” communications functions drive the signal process-

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ing to the antenna and the “inner” communications functions drive the signal processing inward toward the baseband processing.

GSM (Global System for Mobile Communications) networks provide a fundamental ability to define personalities for their devices through the use of SIM (Subscriber Identity Module) cards. The technology of SIM cards provides a central location in the GSM end user device (e.g. mobile station) for defining its personality. User specific and personalized parameters are created, updated and stored in individual SIM cards, allowing the end user device to operate in any GSM network regardless of geographic location. The SIM card authenticates the end user device to the cellular (wireless) network by providing user-specific parameters that uniquely identify the device (and the user) in its environment. Changing SIM cards allows the user to don a new identity in the network. While traveling between networks, particularly in Europe where GSM is the predominant network, users are not required to carry multiple phones and register in multiple networks. Instead, they carry multiple SIM cards to augment their device’s personality in different environments.

The registration of an end user device in multiple networks requires an understanding of the mobility management techniques used in today’s wireless communications networks. The essential components of mobility management are user authentication and location update (registration) of the end user device (e.g. mobile station). These concepts are rooted in the establishment of a “home” area defined by the customer’s wireless service provider. Once subscribed, the entries in the wireless service provider’s database establish the home network for the user. The mobility management systems utilize locational databases which hold the necessary information to authenticate, register and locate any device subscribed to the network as well as to control the provisioning of services subscribed to by the user.

As the user passes through a network to which they are not subscribed, a temporary database is created in the visiting network. The temporary user subscription information stored in the visiting network contains the same end user device information and service information, which is a subset of the information stored in the home network, together with temporary location information which includes its current position. This visiting network database enables the end user device to function within the new networks, with temporary subscription information to route and connect access for the user. Because each foray into a new network will require a stable point in time to reference, a single device usually references back to a single home location. These techniques are only relevant between networks with compatible technologies (for example CDMA or TDMA) and CAI protocols (e.g. GSM, IS-136, IEEE 802.11x).

In current networks, roaming agreements are created as a convenience for customers traveling between geographic areas. Such agreements permit the customer to use their device within a visiting network on a temporary basis and allow access to that network without operator intervention. The Home Network tells the Visiting Network what services the customer is entitled to and the Visiting Network bills the Home Network for those services (later passed on to the subscriber). In current networks, if there is no agreement with the visiting network, the user has to go through an operator to establish a temporary billing arrangement before a call is permitted.

II:

Most of today’s reference architectures are of content delivery networks to accommodate wireless devices, such as (wired) broadband networks being enhanced to include wire-

less extensions for voice and data access. Much of the new innovation has taken the form of providing this support through enhancements to existing technologies.

However, since wireless communications now play a very major role in fulfilling daily communications needs, they should no longer be treated as just extensions of existing wired networks. As wireless communications services are available in many networks with different characteristics (e.g. radio technologies, operating spectrum, bandwidths, signaling protocols, network controls, user controls, etc.), there arises the need to make the access to these different wireless networks as simple and easy as possible for the user. The advances thus far in internetworking for the most part have been applied to large scale wireless networks and are not accessible to in-building, campus-wide or enterprise-wide communications applications. When it is applied to small networks, it is in the form of Wireless LANS, and data only applications.

For example, multimode Radio Cards such as Nokia's recently announced type II/III PC Card indicate support for GPRS (Global Packet Radio System), HSCSD (High Speed Circuit Switched Data) and 802.11b Wi-Fi compliant systems in one device. These devices promise "always on" high data rate services utilizing the packet-based (GPRS) and circuit-based (HSCSD) flavors of GSM and the Wi-Fi Wireless LAN systems.

But multimode Radio Cards address the needs of roaming in data-only environments without addressing voice and video services. The system is also limited to GSM-related and line-of-sight wireless LAN networks. Users outside of these types of systems would have no access. There is a need to extend this roaming freedom to voice and video access as well as technologies other than GSM and CDMA.

As another example, dual subscription services such as those enabled by SchlumbergerSema's smart cards allow two different accounts to co-exist on the same SIM card. These accounts are for GSM networks and are operated singly within the user device (phone). Dual SIM Card technology such as SIM Card Pro is an unusual solution which connects two SIM cards to one user device. The two SIM cards are connected in the user device to a virtual SIM by a cable. The two cards cannot be used simultaneously, and the user device must be reset to switch between the two.

However, manipulation of SIM card technology, also limited to GSM networks, still requires multiple cards for each phone to cover multiple networks. Dual subscription services (limited to GSM), require call forwarding between accounts to have access to both networks. While multiple SIM cards provide access to multiple networks across geographical boundaries, each change of a SIM requires a different telephone number to access the same device. The overall network that is accessible by multiple SIM cards then becomes a patchwork of networks, with clearly defined seams and boundaries, limited by the personality programmed into each card. There is a need for a device which can span multiple networks while maintaining a singular identity.

As yet another example, dual or multi-NAM devices currently available support registering a user device with a different local number in each market. The Number Assignment Module (NAM) is an EEPROM (Electrically Erasable Programmable Read Only Memory) which stores the subscriber specific parameters including the International Mobile Station Identification (IMSI) and the MIN (but not the ESN). This approach is also known as Dual Line Registration, Dual System Registration, or Dual Telephone Number. It maps two

wireless numbers into a single user device allowing services from two wireless networks without incurring roaming charges in either network.

However, dual or Multi-NAM devices require multiple telephone numbers to access the networks to which they are known. A way is needed to be able to recognize the user as a home user regardless of which network they are accessing. This would allow the user to maintain a consistent look and feel across multiple networks.

Preferred Roaming Lists (PRLs) common in current networks to affect multiple registrations, are roaming agreements set up with contracted service providers in different geographical regions. A PRL is a list of five-digit System Identification Numbers (SIDs) which are unique for the service area of the provider and include network types such as Residential, Private or Public serving areas. Upon communicating with any wireless network, the Mobile Switching Center (MSC) provides its SID to the device for identification. The SID is used to distinguish between different networks (for example, "home" and "visitor"). When using a PRL, it is first checked for these other providers when the device is not in its home network. PRLs facilitate communication in foreign networks without requiring operator intervention as in the case of credit card payment.

PRLs exist within a single technology or network, and are not shared between different types of technology (such as between CDMA and TDMA). There is a need for a device that will permit the roaming between different contracted networks regardless of technology.

Other approaches, such as Global Roaming services, Protocol Gateways and Interworking Gateways, facilitate multi-network access by network enhancements which are more expensive as well as technology and network-centric.

Global Roaming services are focused on GSM. Protocol Gateways are designed to provide architectural enhancements to home network databases. Interworking Gateways are targeted at providing flexibility and scaling to very large network configurations.

These approaches do not support the scalability, flexibility and accessibility required for enhanced devices.

The struggle to design End User Devices that are uncomplicated yet powerful tools for network access has resulted in specialized devices providing the most power for the least complexity in specific networks. Voice access has led in this development as the most popular technology in use. Data access is being developed as adjunct cards to computing devices such as PCs and handhelds. Video technology has not progressed as quickly in this arena. Convergence in the form of "smart" devices which support voice with limited data, has not adequately served the business market in need of maintaining a wireless experience comparable to the wired experience as a wireless device moves through different environments of rooms, buildings, states, or countries. There is a great need for a single device that retains a familiar look and feel for its user when it moves through various environments.

IP (Internet Protocol) devices require a specific port with associated IP address which provides a customized user experience. That experience cannot be duplicated at another port, even if network access exists. The user has limited capability in that environment. In a wireless solution, the user can connect to its home network through a wireless portal which does not require an associated address and have familiar and consistent access to its databases and systems.

Present-day SDR technology which facilitates the roaming across multiple network technologies does not expand to allow the user to function within those different networks as a home user. Instead, users are provided with limited access

and extended billing. The frequent travelers of a multi-national corporation need universal access to their networked data and telephony services with the power to change and adapt these services in real-time.

Wireless devices (e.g. telephones) are currently designed with internal codes which only function on one network. In order to gain access to another network, connection to the previous network must be terminated and then re-established in a new network. Service constructs such as Personal 800 numbers address this issue in the wired network arena by creating a single number which locates the user wherever they may be (i.e. residential, business, mobile). However, the wireless requirement of a home area makes such a choice impossible in wireless networks currently. Wireless Number Portability has not been achieved in current networks because numbers are mapped back for routing and billing to the home network. When a user changes "homes", the number stays with the home network and not the device. SIM cards facilitate movement between global GSM networks but also require different access (phone) numbers for each network. A new type of end user device is needed which can function without an "anchor" (home) network while providing that equivalent access across multiple networks.

III:

Today's current handoff process for mobile devices is commonly referred to as a "homogeneous" handoff process, which is a handoff performed between two base stations or two networks that utilize the same radio link technology. This conventional homogeneous handoff process occurs when a mobile station (e.g., a mobile device or a wireless device) is connected via a radio link to a wireless base station and the mobile device is engaged in an active call via a Mobile Switching Center (MSC). During the course of the call, the mobile device crosses into a handoff transition region which is the boundary coverage area between two wireless base stations that employ the same radio link technology and connect to the same MSC or between two wireless base stations that employ the same radio link technology and connect to two different MSCs. The handoff process starts while the wireless device is connected to the first base station and detects that it is in the coverage area of the second wireless base station. The radio link to the first base station is eventually disconnected, and the radio link to the second base station should be established to continue the call. As result, the call session continues without dropping the call.

There are three methods typically used to detect when a mobile device crosses the boundary area and needs a homogeneous handoff:

The mobile device continuously monitors the signals level of the radio link of the surrounding base stations and initiates the handoff process when a predetermined handoff criteria is met.

The surrounding base stations measure the signal transmitted from the mobile device, and the network initiates the handoff process when a predetermined handoff criteria is met.

The network transmits a request for the mobile device to measure the signal from the surroundings base stations.

The network makes the handoff decision based on reports from the mobile devices.

After a request for a homogeneous handoff has been detected, there are two methods to process such requests. The first method is referred to as "an inter-base station" handoff and the second method is called "an inter-system" handoff. The inter-base station homogeneous handoff is a process where two base stations are connected to the same MSC and the call session is maintained on the same MSC before and

after the handoff process. The inter-MSC homogeneous handoff is a process where a homogeneous handoff is conducted, where two base stations are connected to different MSCs and the call session is transferred to a different MSC in order to complete the handoff process. Both of these methods must be completed as quickly as possible, to ensure that the new radio link is established before the old radio link fails to ensure a seamless handoff call session.

Today's mobile handoff process, however, has a major limitation in that it does not permit a seamless handoff in situations where the two radio links in the handoff process utilize different radio technologies, which is referred to as a "heterogeneous" handoff process. This heterogeneous handoff process is not used in today's wireless system because the process cannot be completed in a seamless manner and meet the critical handoff timing requirements without resulting in a drop call. This is because current mobile devices lack the capability to support two independent call sessions both being concurrently conducted on a single wireless device with two different MSCs that utilize two different radio links technologies while still being able to meet the strict handoff timing requirements.

One problem that arises when current wireless devices require a heterogeneous handoff is that the device requiring the heterogeneous handoff must be capable of determining radio links compatibility between the two MSCs before determining if a heterogeneous handoff can be implemented. Each CAI protocol specifies how mobile devices and base stations communicate over radio frequencies and defines the control channel signaling methods. Thus, different wireless networks may have different policies and methods for handling handoff requests. Thus, the exchange of signaling information between the wireless devices connected on a first network to a second network having a different radio technology may be substantial. As the mobile device moves away from the base station of the current network and the mobile signal becomes weak, a substantial amount of signaling information for the handoff request must be processed by the new MSC to complete the handoff before the time expires. If not, this leads to dropped calls. These limitations have restricted the use of heterogeneous handoffs in both inter-base station and inter-MSC handoff applications in existing wireless system.

It is an object of the present invention to address the deficiencies of the prior art.

SUMMARY OF THE INVENTION

A multi-protocol, multi-network device in accordance with the present invention provides a platform for data, voice and multimedia applications in a single unit. Broadband High Speed Internet Access may also be available through the device.

A method for automatically adapting a multi-protocol wireless device to facilitate a seamless multistage handoff according to various exemplary embodiments can include initiating a seamless multistage handoff process using a multi-protocol wireless device when the multi-protocol wireless device crosses a boundary area into an overlapping region where the multi-protocol wireless device is capable of simultaneously accessing a plurality of networks; implementing the seamless multistage handoff process by performing at least a two-stage handoff process comprising a homogeneous handoff and a heterogeneous handoff without interrupting a communication call session conducted using the multi-protocol wireless device; performing the homogeneous handoff between a first network operating on a first communication protocol and a second network operating on a second com-

communication protocol, wherein the first network is an existing network in use by the multi-protocol wireless device at a time of crossing the boundary area and the first communication protocol and the second communication protocol having compatible transmission technologies, and the first network and the second network are different networks of the plurality of networks; and performing the heterogeneous handoff within the second network between the second protocol and a third communication protocol, wherein the second communication protocol and the third communication protocol having incompatible transmission technologies.

A multi-protocol wireless device automatically adaptable to facilitate a multistage handoff according to various exemplary embodiments can include at least one transceiver configured to transmit a request and receive a download to store at least one program into a plurality of Digital Radio Platforms (DRPs) to configure a plurality of Software Define Radios (SDRs), respectively, to store multiple transmission technologies to establish communication simultaneously with a plurality of networks. A memory for storing information in at least one database, wherein the at least one database may be configured to store network profiles for the plurality of networks to enable the multi-protocol wireless device to simultaneously communicate with the plurality of networks. A processor may be configured to initiate a multistage handoff algorithm using the multi-protocol wireless device and the at least one database provides a means to configure a multistage handoff algorithm to select at least one wireless network of the plurality of networks to communicate with when the multi-protocol wireless device crosses a boundary area into an overlapping region where the multi-protocol wireless device is capable of simultaneously accessing the plurality of networks. The multistage handoff algorithm may comprise at least a homogeneous handoff algorithm configured to execute a homogeneous handoff and a heterogeneous handoff algorithm configured to execute a heterogeneous handoff, wherein the multistage handoff algorithm executes the homogeneous handoff and heterogeneous handoff without interrupting a communication call session conducted using the multi-protocol wireless device. The processor may instruct the homogeneous handoff algorithm to execute the homogeneous handoff between a first network operating on a first communication protocol and a second network operating on a second communication protocol when the multi-protocol wireless device crosses the boundary area, wherein the first network is an existing network in use by the multi-protocol wireless device at a time of crossing the boundary area and the first communication protocol and the second communication protocol having compatible transmission technologies, and the first network and the second network are different networks of the plurality of networks. The processor may instruct the heterogeneous handoff algorithm to execute the heterogeneous handoff within the second protocol and a third communication protocol, wherein the second communication protocol and the third communication protocol having incompatible transmission technologies.

A method for automatically adapting a multi-protocol wireless device to facilitate a seamless multistage handoff according to various exemplary embodiments can include initiating a seamless multistage handoff process using a multi-protocol wireless device when the multi-protocol wireless device crosses a boundary area into an overlapping region where the multi-protocol wireless device is capable of simultaneously accessing a plurality of networks; and implementing the seamless multistage handoff process by performing at least a two-stage handoff process comprising a homogeneous

handoff and a heterogeneous handoff without interrupting a communication call session conducted using the multi-protocol wireless device.

A method for automatically adapting a multi-protocol wireless device to facilitate a seamless multistage handoff according to various embodiments can include initiating a seamless multistage handoff process using a multi-protocol wireless device when the multi-protocol wireless device crosses a boundary area into an overlapping region where the multi-protocol wireless device is capable of simultaneously accessing a plurality of networks; and implementing the seamless multistage handoff process by performing at least a two-stage handoff process comprising a homogeneous handoff and a heterogeneous handoff without interrupting a communication call session conducted using the multi-protocol wireless device.

A multi-network client device according to various embodiments can include a controller configured to support multiple independent call sessions, wherein the independent call sessions are concurrently conducted on a single wireless device through the use of parallel communication sessions and simultaneously connect the wireless device to a plurality of different networks hosting different content services.

A method of conducting multiple simultaneous call sessions according to various embodiments can include conducting independent call sessions concurrently on a single wireless device using parallel communication sessions; and simultaneously connecting the wireless device to a plurality of different networks hosting different content services.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, wherein like reference numerals denote similar elements throughout the several views:

FIG. 1 depicts an example of an environment in which an inventive device may be used;

FIG. 2A depicts the architecture of the inventive device in accordance with an embodiment of the invention;

FIG. 2B depicts a data structure in accordance with one embodiment of the invention for storing data on the inventive device of FIG. 2A, the data being used in conjunction with a Position and Protocol Assisted Learning (P²AL) algorithm;

FIG. 2C depicts the database structure of a Network Coverage Map (NCM) data file in accordance with the embodiment of FIG. 2B;

FIG. 2D depicts the database structure of a User Personality Profile (UPP) data file;

FIG. 2E depicts the database structure of a Access Priority Table (APT) data file;

FIG. 3 is a flow chart depicting an overview of the P²AL algorithm and its interaction with the data structure of FIG. 2B;

FIG. 4 is a flow chart of the coverage map synthesis algorithm portion of the P²AL algorithm;

FIG. 5 is a flow chart of the capability update algorithm for the inventive device;

FIG. 6 is a flow chart of the quick access selection (QAS) algorithm portion of the P²AL algorithm;

FIG. 7 is a flow chart of the scan access selection (SAS) algorithm portion of the P²AL algorithm;

FIG. 8 is a flow chart of the common air interface (CAI) protocol selection algorithm portion of the P²AL algorithm;

FIG. 9 is a flow chart of the priority-driven access selection algorithm;

FIG. 10 illustrates the multi-network client device executing a multistage seamless heterogeneous handoff process; and

FIGS. 11A and 11B illustrate an example of execution steps in the multistage seamless heterogeneous handoff process shown in FIG. 10.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, a wireless device **10** in accordance with the invention provides a platform for data, voice and multimedia applications in a single unit which can operate seamlessly across multiple networks that operate with different wireless protocols. Device **10** may take various forms. For example, it may be a computer that has a wireless connection, an advanced type of wireless telephone, etc. Device **10** is provided with SDR capability to enable it to work with any network, not just GSM but also CDMA, TDMA, 802.11x and any other wideband wireless technologies or CAI protocols. Broadband High Speed Internet Access is also available through the device.

The inventive device **10** can communicate with multiple wireless networks as shown in FIG. 1. In the example of FIG. 1, there are a series of overlapping wireless networks, CN_{11} , CN_{12} , WN_1 and CN_{1k} , where CN refers to a "Contracted Network". A user of the wireless device **10** contracts with one or more of the "contracted networks" to be able to obtain wireless service within that contracted network on pre-determined or negotiated contractual terms. The wireless network WN_1 is a network with which the user has not yet entered into a contract (a non-contracted network). As an example, the outermost layered network CN_{1k} might be a wireless network that spans a state. WN_1 might be a local wireless service with only city coverage. A particular block may support wireless internet access to contracted network CN_{12} . Finally, a building on the block may have its own wireless network CN_{11} . Each of the wireless networks CN_{11} , CN_{12} , WN_1 and CN_{1k} may use a different wireless technology, such as GSM, CDMA, TDMA, 802.11x and any other wideband wireless technologies or CAI protocols.

There may also be additional networks such as CN_{21} and CN_{2m} , where CN_{21} is, for example, a network that partially overlaps the coverage area of CN_{1k} and CN_{2m} does not overlap with any of CN_{11} , CN_{12} , WN_1 , or CN_{1k} .

As a result of user movement, the inventive device **10** moves and can be located at different positions such as positions A, B, C, D, E, F, G and H. When a user is at position A, device **10** has four different networks to which it has access. When a user with device **10** is at position B, device **10** has only three different networks to which it has access, etc. When a user is at position E, networks CN_{1k} and CN_{21} are available. When a user is at position H, no wireless networks are available. As explained below, the device **10** is capable of knowing where it is located and what wireless networks are available for it to access. Device **10** can automatically adapt itself to utilize a personality and technology suitable for communicating with a selected one of the wireless networks.

This invention defines the architecture and design of device **10** that greatly expands the capability of current wireless devices to support multiple networks with the ease and advantage of a "home" device appearance. Device **10** is used as a "home" device to access multiple registered networks.

FIG. 2A depicts the architecture that device **10** uses in an embodiment of the invention.

Device **10** comprises a Wideband SDR (Software Defined Radio) Transceiver Platform **100**, a GPS Sniffer/Scanner Receiver **103**, Digital Signal Processing (DSP) Platforms **104**, configuration databases **105**, device I/O **106**, power supply **107**, a controller **108** for controlling device **10** based on

the application firmware and software, firmware/software programs **109** for running device **10**, and one or more Multi-band antennas **110**.

The Wideband SDR Transceiver Platform **100** comprises a Broadband RF Front End Radio **101** and Digital Radio Processing (DRP) Platforms **102**. The Broadband RF Front End radio **101** is a spurious-free high dynamic range broadband radio. This broadband radio **101** allows the invention device to see the full spectrum available to it by scanning the band in segments.

Device **10** partitions the integrated functions in current SDR designs onto multiple ICs for the flexibility of dynamically changing radio personalities in real time. In this partitioned design, the DRP Platforms **102** comprise specialized ASICs (Application Specific Integrated Circuits) that are used for performing common functions within the device **10** such as software radio processing, including channel shaping, tuning, and filtering in a digital domain with up/down conversion and control software. By understanding which functionalities must be performed by all transmission platforms, and by incorporating these generic functions into specialized ASICs a highly flexible structure is realized. These special-purpose ASICs (or "ASIC engines") provide the hard-coded logic used to configure the Digital Radio Processing (DRP) Platforms. General-purpose ASICs such as DSPs (Digital Signal Processors) **104** are used to perform the programmable tasks. The DSP contains the control software that is used to call and control the functions implemented in the specialized ASICs. Programs downloaded or stored in the DSP configure the device **10** according to specific applications, allowing it to conform to the target network. This approach provides maximum flexibility, programmability and re-configurability.

The digital radio processing function provides the programmable capability to switch the invention device from one radio technology to another. Changes in the network selected by device **10** for communication cause a personality adjustment in the device that dynamically alters the technology (i.e. CDMA, TDMA, etc.) and CAI protocol (i.e. GSM, IS-136, cdma2000, IEEE 802.11x etc.) that are needed to communicate with the selected network. The wideband front end radio and the antenna change thus frequencies accordingly. These changes are made by dynamically transferring new parameters into the DRP Platforms **102**, thereby enabling device **10** to be usable for multiple networks and technologies.

The GPS Sniffer/Scanner Receiver **103** receives real-time geographic position information from GPS satellites. This portion of the invention device remains active even when the device **10** is turned off. Device **10** routinely scans for geographic positioning and stores the results in its configuration database. The GPS Receiver **103** provides a time-stamped position-based identification of the location of device **10**, taking advantage of GPS receiver technology. The GPS scanner/receiver includes a "sniffer" function which continuously scans for the presence of GPS location data to determine the position of device **10** within a network. As further described below, the results of these scans are time-stamped and stored in the invention device location database (Network Coverage Map) for later retrieval.

The DSP (Digital Signal Processor) Platform **104** comprises a set of DSPs and associated processing, including baseband processing and channel signal processing. The baseband processing provides modem and codec functions. The DSP Platform **104** stores the firmware and algorithms ("personality" profiles) that are used to facilitate communication between the invention device and the network. The digital signal processing function provides the necessary processing of signals for the associated radio technology and

CAI protocols, including the baseband processing which provides the baseband features and input/output signal conversions, such as modem, speech codec, video compression, etc.

To access a contracted network, the appropriate network “personality” profile is transferred to the DRP (digital radio processing) Platform **102** which changes device **10**’s CAI protocol identity.

The user I/O devices **106** (such as display, keypads, speaker, etc.), power supply, controller **108**, and the multi-band antenna **110** are standard products. For example, I/O devices **106** and power supply **107** are commercially available from Analog Devices, controller **108** is commercially available from ARM Ltd., and antennas **110** are available from Galtronics. At least some of these components are alternatively available from ArrayCom.

FIG. **2B** illustrates a high-level view of an embodiment of the database structure used in conjunction with a Position and Protocol Assisted Learning (P²AL) algorithm. The P²AL algorithm is loaded as an application in memory in device **10** and is used by device **10** to select a wireless network with which to communicate when device **10** is located at a particular location. These configuration databases **105** are described in three segments: Location Profile data **200A**, User Personality Profile (UPP) data **200B**, and Access Priority Table (APT) data **200C**. For the purpose of this application, the words table and profile are used interchangeably. The form or structure in which the data is contained is irrelevant to the present invention. One of ordinary skill in the art would understand that many different organizations and structures of data could be utilized to achieve the functional objectives of the present invention. Each of these segments consists of two components. In the Location Profile segment **200A** there is GPS data **201** (also described as “GEO”—short for geographical—in later flowcharts) and Network Coverage Map (NCM) data **203**. In the UPP segment **200B**, there is Network Profile data (NP) **205** and Access Personality (AP) data **207**. And in the APT segment **200C** there is contracted network Access Priority data **209** and CAI (Common Air Interface) Protocol Access Priority data **211**. Configuration databases **105** may also include data for the CAI protocol and other databases which provide a means to configure the software of device **10** to adapt to any network in which it may find itself. Databases **105** may contain network profiles for multiple networks to enable device **10** to configure itself to communicate with any of these networks. These databases contain data that are either gathered by the device **10** or permanently stored in the device **10** to facilitate these changes.

The GPS data **201** comprises geographic position data stored in the device **10** that is used to help pinpoint the location of device **10** within its current environment and with relation to the contracted networks for which it has coverage **202**, as the invention device defined coverage area. The Network Coverage Map data **203** represents coverage area map boundary data that is stored in the device **10** for each contracted network. The NCM data may be created at device **10** or downloaded. When device **10** is used, this boundary data is used as a starting point for building out more detailed maps by using the collected GPS data to synthesize (create) yet more data points. These additional points of GPS data are then incorporated into the coverage maps **204**.

In using the invention device with current networks, network-specific identifiers (Network Profile, NP) and user-specific access information (Access Personality, AP) are created and stored within the invention device as the User Personality Profile **200B**.

The User Personality Profile database is able to store as many “personality” profiles as desired. The limitation to the

number of profiles is the complexity of the hardware required in storing large amounts of data. The UPP **200B** also supports several levels of VPN security access including basic over-the-air (OTA) security, so-called “tunneling” point to point VPN and point to multi-point VPN access, mission-critical dynamic keying scheme, and any other pre-determined levels. The OTA is basic encryption over the air interface. Tunneling provides a direct access to either another device in the system (point to point) or a group of devices (point to multi-point). The mission-critical levels provide a dynamic keying scheme with selectable keys for enhanced security access. The security levels are user-selected at initialization and dynamically adjustable at any time. The invention device stores as many UPPs as desired, one for each contracted network.

The Network Profile data **205** represent specific network profile information for each contracted network. A Network Profile captures the contracted network uniquely, including CAI protocol, SID, device identifiers, etc. Thus, this data provides the parameters of a contracted network for the invention device to create the corresponding personality/identity (e.g. CAI protocol, SID, device identification, etc.) to allow it to communicate with that particular contracted network **106**. For each contracted network, there is a network profile signal processing image stored in the DSP Platform as a load module. These signal processing “programs” are prioritized under user control, creating preferred modes for the invention device. To select a contracted network, the appropriate firmware load module is transferred to the DRP. The image is used to configure the broadband RF front end radio aspect of the transceiver function.

The Access Personality data **207** contains the specific user identity and user services associated with device **10** and its user for each contracted network. Thus, data **207** provides previously stored user identification information (e.g. Personal Identification Number, PIN) and the preferences and service contracts associated with the user to activate the invention device for service access within a particular contracted wireless network **208**.

An Access Personality represents the user uniquely in each of the contracted networks. As the user enters a new network and tries to establish communication, the priority with which it communicates to its contracted networks is consulted, and the geographic position data is compared against the stored Network Coverage Map data to determine which contracted network the invention device may access. Without that match, the invention device runs through a scanning algorithm assuming the device personality for each contracted network in order of priority and attempting communication. If a match is found with one of the contracted networks, then the corresponding AP is sent to the network, and normal authentication ensues.

If no match is found, the real-time transaction-based service access method is invoked.

Using the invention device in an enhanced wireless network architecture provides the flexibility of creating a Temporary Network Profile to map the Current NP to the invention device’s Network Profile list. This Temporary NP is used by the invention device to communicate with the enhanced network to determine what temporary identifiers (e.g. User Personality Profile, Access Priority Table, and Network Profile) should be created for the non-contracted network. The temporary assigning of these identifiers is a transaction service which allows the user to have a common experience on this foreign network.

The contracted network Access Priority data **209** stores a user-defined access priority table for accessing the contracted

networks in order of user-defined priority **210**. The Common Air Interface Protocol Access Priority Data **211** is likewise a user-defined priority table that sets the priority for device **10** to select one of the available CAI protocols. Device **10** uses the CAI protocol parameters to scan the environment by communicating with the network and determine whether a contracted wireless network is present within its location. Object load modules (i.e. CAI protocol images) representing each supported Common Air Interface protocol are stored in a CAI protocol database. Additional load modules are downloadable to the invention device to adjust for future enhancements in CAI protocol technology.

Thus, six components, organized under three segments or files, come together to form the complete database for the P²AL algorithm.

As discussed above, FIGS. **2C**, **2D**, **2E** show a logical structure of the respective separate NCM, UPP and APT databases of FIG. **2B**. The Network Coverage Map database consists of contracted networks with boundary point information on the coverage area maps. The User Personality Profile database consists of Access Personality data for each stored contracted network which holds specific user identification and service requirements on each contracted network, and Network Profile data for each stored contracted network which allows the invention device to configure itself to communicate with the contracted network. The Access Priority Table database consists of contracted network access priority information for position assisted learning and Common Air Interface protocol access priority information for protocol assisted learning.

FIG. **3** shows a flow chart for the Position and Protocol Assisted Learning (P²AL) algorithm with its sub-algorithms. The P²AL algorithm comprises multiple sub-algorithms including a Position Assisted Learning algorithm **301** and a Protocol Assisted Learning algorithm **307**. The former comprises a Coverage Map Synthesis algorithm **303** and a Quick Access Selection algorithm **304**, while the latter comprises a Scan Access Selection algorithm **310** and a CAI Protocol Selection algorithm **311**. (In addition, device **10** also has a Capability Update Algorithm (see FIG. **5**) to enhance its capabilities via physical contacts (e.g., a wired connection) or over the air download in real time, originated either by the invention device (user) or by the network.)

The P²AL algorithm assumes that a user has established one or more contracted networks. Upon initialization, device **10** calls up its list of contracted networks and displays them to the user at step **309**. The user is able to select (or rank) the priority order in which contracted networks are to be accessed. For example, if there are contracted networks **1**, **2** and **3**, the user may specify that CN**2** should be selected before CN**1** and CN**3** for whatever reason, such as perhaps CN**2** has a better pricing structure or better service. The rank order of priority which is selected is then stored in the Access Priority Table **200C**. If the rank order is pre-specified at an earlier time, step **309** may be skipped. Next, device **10** uses the information in the APT **200C** and proceeds to the Position Assisted Learning algorithm **301** where the GPS database **201** is accessed for current data on the device's geographic position. When both geographical and access priority information are available at device **10**, device **10** identifies the available contracted network at its location to access using Location Profile data **200A** and transfers the appropriate parameters from the User Profile Personality data **200B** in database **105** to the SDR Transceiver Platform **102** and Digital Signal Processing Platforms **104** to attempt service access to that network.

If current GPS geographic information is available, the P²AL algorithm proceeds to step **303** where the CMS algorithm compares real-time GPS data received by device **10** with its currently stored boundary information Network Coverage Map for the contracted network in which it is currently activated to determine if there is a match. If there is no match (i.e., device **10** does not have boundary information for the selected network), the algorithm updates the NCM **203** with the new coordinates, providing a more accurate view of the device's coverage areas. The CMS algorithm **303** runs continuously, using real-world data to create wireless network coverage maps with increased accuracy and completeness.

The Position Assisted Learning algorithm also comprises a QAS algorithm **304**. The QAS algorithm **304** analyzes the real-time GPS data **201** and uses it to identify available contracted networks at its location. It uses the Access Priority Table **200C** to determine which one to select first if there is more than one. For each available contracted network, from the User Personality Profile **200B**, it retrieves the necessary user information from the Access Personality profile data **207** to configure the invention device and retrieves network information from the Network Profile **205** to try to communicate with available contracted networks.

If geographical information is unavailable, device **10** uses a Protocol Assisted Learning algorithm **307** which utilizes an iterative loop described below to determine the available network, if any, at its location through a process of elimination. The Protocol Assisted Learning algorithm **301** would thus be invoked if there is no GPS data available at device **10** (for example, certain building interiors or other areas in which signal data cannot be received).

The Protocol Assisted Learning algorithm first calls on a Scan Access Selection algorithm **310**. Algorithm **310** uses an iterative process of adopting the personality of each contracted network of which it has a record in memory and attempts to communicate with the selected network. The SAS Algorithm uses the Access Priority Table **200C** to define the order in which it scans for available contracted networks. It uses the User Personality Profile **200B** to get the Network Profile information **205** necessary to dynamically configure device **10** to attempt access with the selected contracted network. Receipt of a real-time GPS data interrupt stops processing of the SAS algorithm **310** and sends the device **10** back to its Quick Access Selection (QAS) algorithm **304**. The SAS algorithm **310** invokes the CAI Protocol Selection algorithm **311** if it exhausts its APT and does not find any contracted network. Like the SAS algorithm, the CAI Protocol Selection algorithm **308** uses an iterative process with CAI Protocol Access Priority information from the APT **200C** to look for available networks by implementing CAI protocols to scan in sequence.

The following sections provide more detailed descriptions of the sub-algorithm components of the P²AL algorithm and its complementary Capability Update Algorithm.

FIG. **4** shows a detailed flow chart for the Coverage Map Synthesis (CMS) algorithm **303**. This algorithm is an ongoing process as GPS data is dynamically gathered by the invention device **10**. Through this algorithm, the device can update its memory to include networks discovered by its searches. Before the CMS algorithm begins, at step **401**, GPS data is acquired. The algorithm starts at step **402**. At step **403**, the algorithm determines whether device **10** is service ready (that is, whether it has registered with and been authorized by a network and is ready to make and receive calls). If it is service ready, at step **404** device **10** accesses time-stamped information from the GPS receiver. As that information is stored in the Geo database **201**, it is compared at step **406** with

the existing Network Coverage Map database **203** for the current contracted network. If it is not within the boundary of the NCM **203**, the NCM is updated at step **407** to reflect the additional information. If the geographic data indicates that device **20** is within the NCM is already accurate and complete, no update is needed and the CMS algorithm ends at step **409**.

FIG. **5** shows the Capability Update algorithm for device **10**. As discussed earlier, the inventive device is capable of requesting an update to support its communication with a new network. This update may be for the purpose of downloading an entirely new protocol, or for downloading an update to a known protocol. The update can occur as a result of a user request, or be initiated by a network (step **501**). A network-based update is a network-initiated over-the-air download to the invention device **10**. Typically, this update would occur when the inventive device first comes into contact with a new network operating with an unknown protocol. The update does not require user intervention and is used to provide periodic updates to the invention device. A user request can take the form of either an over-the-air request or a "physical" (i.e. service center or office) request in which the device is brought in for a stand-alone download. The algorithm starts at step **502**. The device **10** has the capability to download updates to any of its configuration databases. The new parameters are downloaded at step **504**. The Configuration Database **105** in device **10** are updated at step **505** with the new information. In this way, new technology support, or new functionality can be added to the inventive device's flexible architecture. The Capability Update algorithm ends at step **506**.

FIG. **6** shows the detailed flow for the QAS algorithm **304** portion of the Position and Protocol Assisted Learning (P²AL) algorithm. The algorithm **304** determines what contracted networks are available for access at this (new) location where device **10** is moved. The algorithm **304** is triggered at step **601** by either the initialization or power up of the device, or as the inventive device crosses the boundary of two networks. This latter event would occur, for example, when device **10** exits the coverage area and needs to find a new network with which to register. Data gathered from the GPS Sniffer/Scanner Receiver **103** is stored in the Geo (geographical) database **201**. The algorithm starts at step **602**. At step **605**, the QAS algorithm determines available contracted networks by comparing the instantaneous location data to the boundary data stored in the Network Coverage Map database **203**.

If a contracted network is present, as determined at step **606**, a check is made at step **610** to see if there is more than one available contracted network. If no contracted network is present at step **606**, the SAS Algorithm is run at step **607**. If there is a match but with only one contracted network, the Network Profile information for that network is retrieved by the invention device **10** at step **611**. At step **612**, the appropriate CAI Protocol image is transferred to the Digital Radio Processor Platform **102** and thus sets the invention device **10**'s radio parameters to the appropriate Common Air Interface protocol. Along with the other network-specific parameters, the invention device functions with the necessary personality to interact with the contracted network. At step **613**, the invention device **10** then attempts to communicate with the available contracted network. For example, if the geographic positioning of the invention device **10** places it within a network such as AT&T or Sprint, then that network's image is transferred to DRP **102** and the device **10** assumes the personality (technology and frequency) of a device contracted with that network. When the network responds, the

communication is confirmed at step **614**. If the contracted network is confirmed at step **615**, at step **617**, the invention device **10** transmits user-specific Access Personality data stored in the UPP **200B** to identify itself to the network, and standard registration and authentication ensues at step **618**. If the registration and authentication is successful (step **619**), device **10** is ready for service at step **620** and the QAS algorithm ends at step **621**.

If there is a match at step **610** based on NCM data **203** with more than one contracted network, which indicates that the device **10** is located within overlaid networks, then the device **10** creates a list of these contracted networks at step **625**. It uses the Access Priority information **209** from the APT **200C** at step **609** to determine which of the identified contracted networks should be accessed first. For example, if the geographical data places the invention device in both an AT&T and a Sprint network, then the Access Priority Table **200C**, previously set by the user, is consulted to determine which network is preferred by the user. That is, the network with which the device **10** attempts to register. Once it has made that determination, the Network Profile information **205** stored in the UPP **200B** for that network is retrieved by the device at step **611**. The appropriate CAI Protocol image is transferred to the DRP **102** at step **612**, setting the device's radio parameters to the appropriate Common Air Interface protocol. Along with the other network-specific parameters, device **10** functions with the necessary personality to interact with the network. The device **10** then repeats steps **613**, **614**, etc. as described above.

If the first registration and authentication process is not successful at step **619**, and if, at step **622**, there remain other contracted networks for which registration and authentication was not yet attempted, at step **624**, the invention device **10** loops back to step **611** to load the specific parameter information of the next contracted network in the contracted network access priority list **209** and attempts the communication again. If the QAS algorithm **304** at step **619** exhausts the list of contracted networks and is unable to locate a contracted network at the position indicated by the GPS data, device **10** at step **623** invokes its Scan Access Selection algorithm **310** to dynamically scan for available contracted networks. Similarly, if there is no GPS data available or if the received GPS data does not appear to be within the stored coverage area maps of any of the contracted networks, the device **10** will also invoke its Scan Access Selection algorithm **310**.

FIG. **7** shows a detailed flow chart for the SAS algorithm portion of the Position and Protocol Assisted Learning (P²AL) algorithm or, more particularly, of the Protocol Assisted Learning algorithm. The SAS algorithm is triggered if there is no available GPS data or if no available contracted network is identifiable by device **10**. This may be because no contracted network is available according to the Network Coverage Map database **203** or no available contracted network is identified by the instantaneous geographical position data. If there is no GPS data available or the GPS data does not locate an available contracted network from the stored Network Coverage Map data (step **701**) device **10** starts the SAS algorithm at step **702**. The SAS algorithm uses the user-defined Access Priority Table **200C** at step **703** to determine the first contracted network in the order of priority (predefined by the user) to be attempted for registration and authentication.

At step **706**, the Network Profile **205** stored in the UPP **200B** is retrieved for the contracted network. At step **707**, the appropriate CAI Protocol image is transferred to the DRP platform **102**, thus setting device **10**'s radio parameters to the appropriate Common Air Interface protocol. Along with the

other network-specific parameters, device 10 adopts the necessary personality to interact with the selected contracted network at step 708. At step 709, device 10 then attempts to communicate on a control channel with the contracted network to try to confirm whether the selected contracted network is available. If the network responds with an acknowledgement that a contracted network has been found, at step 710, device 10 requests its SID information. Once received, the communication is confirmed. The invention device 10 then retrieves user-specific Access Personality data at step 711 and transmits the Access Personality data stored in the UPP 200B to identify itself to the located network. Standard registration and authentication process ensues at step 713. If the registration and authorization are successful in step 714, at step 716, device 10 is ready for service and the SAS Selection algorithm ends at step 712.

If the contracted network is not confirmed at step 710, the algorithm records the contracted network in an attempt log, and, if the list includes another contracted network at step 715, an iterative loop is processed at step 717 to attempt communication with the next contracted network in priority from the APT by returning to step 706. The iterative loop continues until a communication can be established or until device 10 has reached the end of its user-defined contracted network Access Priority list. If device 10 is able to communicate on the network's control channel, it then attempts to register and authenticate with the network at step 713. If the invention device fails to be authorized (i.e. the network did not acknowledge its communication), then it knows it is being rejected (although it is the correct common air interface protocol and the correct contracted network) and the SAS algorithm ends at step 712.

If the APT is exhausted without finding a contracted network with which to communicate, this SAS algorithm concludes, at step 718, by running the CAI Protocol Selection algorithm 311 of the P²AL Algorithm.

When searching by CAI protocol in CAI Protocol Selection algorithm 311, device 10 employs a control Digital Radio Processing section 102 in which a control channel access algorithm is stored for each contracted CAI protocol to allow device 10 to read any control channel. When starting the search, device 10 assumes the CAI protocol of the technology listed first in the CAI Protocol Access Priority Table 211 (for example, cdma2000). Device 10 transmits through the control channel and attempts to communicate with any available network. The invention device looks for a network acknowledgement and the network's SID (System Identification) information. If the communication is confirmed, the device requests a service transaction and informs the user. If not, it assumes the personality of the next highest CA Protocol (for example, IS-136) and repeats the process of attempting to locate an available network. When an available network is located, that network's image is transferred to one of the DRPs. The device functions with that personality. Upon acknowledgement from the network, the device transmits user-specific Access Personality (AP) data to identify itself to the network, and standard registration and authentication ensues. The combination of the control channel and the SIDs are used within the P²AL algorithm to determine information about the device's location and environment.

Throughout this process, a real-time geographical data interrupt at step 719 is possible from the GPS receiver. This indicates that geographical positioning data has become available. Upon receiving the interrupt, the SAS algorithm is dynamically interrupted and device 10 runs its Quick Access Selection (QAS) algorithm.

FIG. 8 shows the detailed flow chart for the CAI Protocol Selection algorithm 311 portion of the Position and Protocol Assisted Learning (P²AL) algorithm. If no contracted network is available at step 801, the CAI Protocol Selection algorithm starts at step 802. At step 803, device 10 retrieves the CAI Protocol Access Priority parameter data from the Access Priority Table 200C at step 804 and retrieves the first priority CAI Protocol. The appropriate CAI Protocol image is transferred to one of the DRPs at step 805, thus setting the device's radio parameters to run the appropriate Common Air Interface protocol (e.g., cdma2000). The device 10 then attempts, at step 808, to communicate on a control channel to any located network. If a network responds with an acknowledgement at step 809, the device requests its SID information. Once received, the communication is confirmed. Device 10 requests a service transaction and informs the user in step 810. If the communication is not confirmed, then it is not the correct control channel. If no network is found on a particular CAI, the algorithm checks at step 807 whether the list of CAIs has been exhausted. If not, the next priority CAI will be tried at step 806 and device 10 assumes the personality of the next highest CAI protocol stored in the APT 200C. If no network is found at step 807, a "No Service" message will be displayed at step 812. If a network is found, the user will be alerted at step 810 and the device will be ready for service at step 811. The CAI Protocol Selection algorithm ends at step 813.

The CAI Protocol Access priority table 200C is thus defined by order of air interface preference—for example, GSM followed by IS-136 then cdma2000. Each CAI protocol control channel is accessed in order of priority for an available network in which to activate service. Following the above example, the device 10 assumes a GSM personality and attempts to communicate on a control channel to any available network. If a network responds with an acknowledgement, device 10 requests the network's SID information and a service transaction and alerts the user for operator-assisted temporary registration with that network. If there is no response from any network through this CAI protocol, the next preferred CAI protocol is then used for network seeking. In the example, an IS-136 personality is then assumed and communication attempts are made on those control channels, etc. This iterative selection process continues until a network is found. If the CAI Protocol Access Priority Table is exhausted without finding an accessible wireless network, the invention device displays a result of "no service" in current wireless networks. However, in an enhanced network, the invention device facilitates real-time downloads of additional CAI protocol parameters to gain access to available networks. The Capability Update Algorithm in FIG. 5 is used for this with the APT 200C as the configuration database to be updated and the new parameters as new CAI protocol parameters.

Device 10 also introduces a mechanism for real-time transaction-based services. With real-time transaction-based services, the user can make a one-time arrangement with the network for temporary usage of services. A unique billing authentication code is stored permanently within the configuration database. The device 10 prompts the user for the special PIN and codeword combination to unlock its internal billing authentication code and user identity profile information. The billing authentication code is associated with a specific billing account by the customer. A special transaction identity profile is also stored within the User Personality Profile database, providing unique service configuration information for the invention device to the network. Both are activated by the special PIN and codeword sequence. Once entered by the user, the network gains access through the invention device to

the unique authentication billing code number and user transaction profile. The invention device then functions like a calling card (credit card, or pre-paid card)-which allows the network to bill that account number.

In this mode, the invention device does not require a "Home Network" for its temporary service use. The invention selects the first CAI Protocol in the CAI Protocol Access Priority List and attempts communication on the control channel, and when acknowledged by the network initiates a transaction as a temporary user, using the invention device to facilitate the transaction. Service activation is then based on this transaction opportunity.

The P²AL algorithm is flexible and modular in construction. As a result, the flow can be manipulated to achieve increased efficiency, flexibility or capability in the invention device in a particular application. For example, a priority-driven access selection algorithm for the invention device combines the QAS and SAS selection algorithms into a single algorithm driven by the user-defined Access Priority Table.

FIG. 9 is a rendering of one version of a priority driven access selection algorithm. This algorithm starts at step 901. At step 902, the first priority contracted network is determined from the APT 200C. It then runs a Quick Access Selection loop in which it looks for geographical position data 201 (step 904) and, if available (step 906), compares it to the NCM 203 for the first priority contracted network to determine if the invention device is in the coverage area of the first priority contracted network (step 908). If the instantaneous geographical position data and the NCM indicate that the device 10 is not in the coverage area of the first priority contracted network (step 910), the device then immediately returns to the APT list (step 902) to identify the next priority contracted network to which to attempt access. If there is no geographical data or if the NCM data confirms the invention device is in the coverage area of the first priority contracted network (step 911), the Network Profile information stored in the UPP 200B for that network is retrieved by the device 10 (step 912). Next, at step 914, the appropriate CAI Protocol image is transferred to one of the DRPs, setting the invention device's radio parameters to the appropriate Common Air Interface protocol. Along with the other network-specific parameters, the invention device functions with the necessary personality to interact with the selected contracted network (step 925). The invention device then attempts to communicate on a control channel with the contracted network (step 915). If the network responds with an acknowledgement, the invention device requests its SID information. Once received, the communication is confirmed (step 916). In step 917, the device then transmits user-specific Access Personality data stored in the UPP 200B to identify itself to the network, and standard registration and authentication process ensues (step 918). If the registration and authentication is successful (step 919), device 10 is ready for service (step 922) and the algorithm ends (step 924).

If the contracted network is not available at step 911, the communication is not confirmed at step 916, or the registration and authentication process is not successful at step 919 (and the priority list of contracted networks is not exhausted—step 920), the next priority contracted network is determined (step 923). The invention device loops back to step 904 and loads the specific parameter information for the next contracted network in the priority list and attempts the communication again. If the device exhausts the contracted networks in its Access Priority Table without finding a match (step 920), it calls its CAI Protocol Selection algorithm (step 921) to dynamically scan by the CAI protocol for available networks.

While the flow chart of FIG. 9 shows that the device also checks geographical position information when looping back to load the next priority contracted network, that loop can be bypassed in favor of simply loading each contracted network in turn. In mobile situations, the former is more efficient. When stationary, the latter approach is more effective.

The P²AL algorithm is network independent. The device 10 is able to take advantage of its User Personality Profile database to authenticate to any network without requiring a home (anchor) network. After an appropriate image is transferred to one of the DRPs and communication is successfully completed with the network (via its acknowledgement), the User Personality Profile information is transmitted to the network and authentication is completed between the invention device and the service activating network alone. No Home Network is required. Temporary service activation is also completed this way.

The practical application of SDR in this invention device creates the capability of dynamically asserting the proper personality from multiple identities for accessing a particular network without user intervention. The invention device is agile and robust enough to be used to access wide-area wireless networks as well as in-building, campus and enterprise wireless networks. The device's application of SDR supports dynamic real-time CAI protocol technology adaptation. The invention therefore supports the access of ad hoc networks by downloading CAI protocol parameters directly into the invention device over the radio link.

GPS receiver technology is readily available for use in current wireless devices. The invention device uses GPS technology in a unique and innovative way to provide the capability to accurately "see" its environment and "map" its location with respect to the coverage areas the current network supports. The invention uses this GPS data as the basis for a position-based "quick-access" scheme to "find" and register with a preferred network quickly from multiple available networks.

The device uses location, network, user and CAI protocol and other configuration databases to capture or create information about itself and provide a means to configure the device to function within any network in which it can register. The invention creates a platform for holding primary registration information for multiple independent networks without having to emulate the complete network service provider databases.

While the invention device 10 can function in current wireless networks, its inherent design does not require a home or anchor network to activate service in a contracted or visiting network. The invention device's user profile configuration database creates a unique means for home network independent service activation by storing the invention device's user-specific network parameters for transmission to the current network where service is requested. The invention device functions independently of a home network by providing its user service profile, user identity (portable number) and if necessary, billing code, to the contracted network it is accessing.

Within current network architectures, the invention device redefines the method for "roaming" by using its multi-personality capability to create additional "home" environments in the invention device's frequently visited networks, with all the capabilities and features of a home network. The invention device creates a platform for real-time transaction-based service arrangements in less frequently visited networks. This real-time transaction processing uses a unique encrypted billing code accessible by a special PIN and codeword to make a one-time arrangement between the network and the invention

device for temporary use of their services. When the code-word is activated, the charging algorithm is a function of the physical location of where the device is in the network which is determined by the geographical position data. This capability of the invention device creates a platform for location-based billing which allows the network to charge relative to its position in the network. It provides an accurate description of how many resources are used for a particular transaction.

The invention device provides an innovative approach to Wireless Number Portability by storing an encrypted telephone number within its user identity profile database for transmission to any network where service activation is required. The user unlocks the number from the user identity profile database via a unique PIN and codeword so it can be extracted by the contracted network. The invention device also has the flexibility to have a permanent number assigned which travels with it from network to network. As the invention device registers in a network, it leaves a trail of its presence. When the land line system attempts to locate the invention device, it will find all of the networks in which it has previously registered. The land line system will then page each identified network sequentially to locate the invention device's current location. Prior art SIM cards facilitate moving access numbers from device (phone) to device by moving the SIM card, but that card must be changed if the user travels to a different service provider. In contrast, the invention crosses those boundaries providing access to any network with the same physical device to seamlessly handoff without hardware changes. The invention device supports personal telephone number capability in enhanced networks by providing access to a unique number in the device for the network. The invention device can therefore be reached in any network.

As explained above, this invention device stores a user "personality" profile corresponding to each wireless network with which it has contracted. These "personality" profiles allow the device to access any of its contracted wireless networks as a home user in that network. The invention device is able to recognize these contracted networks by means of network identity profiles stored in a table and dynamically compared to the current network the invention device is located within. As such, the invention device recognizes a contracted network and sends a request to that network. Once the network recognizes the invention device, the invention device receives an acknowledgement that permits it to register. The invention device then sends the appropriate "personality" information to the contracted network. These tasks are all accomplished without administrative intervention of the user. With the ability to appear as a "home" user in many different contracted networks, the invention device changes the way a user can travel ("roam") through many different networks. The invention device breaks down the current necessity of "home" and "visiting" differentiation.

When crossing contracted network boundaries, the invention device performs a "user-defined" hand-off scheme by only handing off to another available contracted network according to the Access Priority Table (APT). This provides the user with flexibility to not just hand off to an available network which may have a higher usage charge rate, different grade of service or in which a transaction would be necessary, but to a preferred, lower cost, better coverage network of user's choice.

Various embodiments of the multi-network client device enable a seamless multistage handoff process and algorithm, without dropping a call session, making such embodiments suitable for heterogeneous handoffs for both "an inter-base station" handoff and "an inter-MS-C" handoff.

In order for the multi-network client device and method to meet the seamless handoff timing requirement of today's wireless systems, the handoff process, in various embodiments, is divided into multiple stages to allow the multi-network client device to simultaneously interface with multiple base stations concurrently using different radio link protocols and technologies. As described above, the multi-network client device has the capability of simultaneously connecting to multiple base stations through the use of a multi-function Software Define Radio (SDR) access subsystem. The SDR access subsystem may include multiple radios (DRPs). Using the multi-network client device during a heterogeneous handoff, new radio parameters having different radio link protocols and technologies can be downloaded into each radio to establish multiple simultaneous independent call sessions with different base stations.

The use of the multi-network client device, as described herein in various embodiments, allows the handoff process to be carried out in multiple stages. In some embodiments, the handoff process can be implemented in a single stage. Various embodiments of the Multistage Seamless Heterogeneous (MSH) handoff process may consist of a homogeneous "inter-MS-C" handoff followed by a heterogeneous "inter-base station" handoff all performed as part of a single handoff process from the perspective of the multi-network client device.

The first stage of the MSH handoff process may include an Inter-MS-C handoff that utilizes a conventional inter-MS-C handoff algorithm which is designed to facilitate a handoff between two wireless networks consisting of the same type of radio link technology, such as, for example, a handoff from GSM to GSM. This stage of the process is designed to move the call seamlessly from one wireless network to another wireless network while meeting the inter-MS-C homogeneous handoff time requirements utilizing inter-MS-C signaling messages. The next stage of the multistage handoff process may consist of a heterogeneous inter-base station handoff process designed to facilitate an inter-base station handoff utilizing intra-MS-C signaling messages within the same wireless network by utilizing a multi-function software define radio (SDR) assembly.

As described previously, the multi-network client device may include multiple radios within the SDR assembly which are capable of receiving newly downloaded radio parameters to establish and conduct multiple simultaneous independent call sessions with different base stations using different radio links protocols and technologies. The different types of radio link technologies may be, for example, CDMA, TDMA, CSMA, OFDA, GSM, cdma2000, IS-136, IEEE 802.11x, IEEE 802.16x, etc. all under software control. The above list is not an exclusive one. Those having skill in the art would understand that other radio links protocols and technologies may be employed.

In addition to or in lieu of the multiple radios being installed within the multi-network client device, in some embodiments, the MSH handoff process may be employed utilizing a multi-function software define radio (SDR) base station that can be dynamically configured to correspond to different types of radio link technologies such as, for example, CDMA, TDMA, CSMA, OFDA, GSM, cdma2000, IS-136, IEEE 802.11x, IEEE 802.16x, etc. all under software control. Likewise, the SDR is used in this embodiment to facilitate seamless handoffs between different types of radio link technology subsystems within the same wireless network or the same wireless base station.

When using the multi-network client device to conduct a call in the heterogeneous inter-base station handoff stage, the

call is transferred to the same wireless network and is controlled at that particular base station, which will be explained in more detail with reference to the exemplary embodiments of FIGS. 10 and 11. The handoff timing that is normally required for signaling between the two MSCs of the different wireless networks is reduced, and as a result the heterogeneous inter-base station handoff can be completed within the required time for a homogeneous inter-MSC handoff process.

FIG. 10 illustrates the multi-network client device 1000 executing a MSH handoff process. The multi-network client device 1000 in FIG. 10, similar to FIG. 1, can communicate with multiple wireless networks. In the exemplary embodiment of FIG. 10, there are two networks, public network NTW₁ and private network NTW₂. Private network NTW₂ overlaps public network NTW₁. Public NTW₁ is a public network 100 based on a public network Common Air Interface (CAI) Protocol 1 which is known as an existing protocol by the multi-network client device 1000. Public NTW₁ provides mobile data communications for mobile devices, such as the multi-network client device 1000, located in the public coverage domain area 1001.

In this example, private NTW₂ is a private network that is capable of supporting both the public network CAI Protocol 1 as well as a private network CAI Protocol 2 within a single base station or a combination of base stations within the same network. The private network NTW₂ includes two different private coverage areas, a multi-protocol private coverage transition domain area 1002 and private coverage domain area 1003. The multi-protocol private coverage transition domain area 1002 supports both CAI Protocol 1 and CAI Protocol 2. The private coverage domain area 1003 supports CAI Protocol 2. It should be understood that the communication profiles shown and described with reference to FIG. 10 is nonlimiting and exemplary only. Those skilled in the art would understand that various profile configurations may be envisioned for the different networks without departing from the scope of the present teachings.

When using the multi-client network device 1000 for performing a MSH handoff process as depicted in the exemplary embodiment of FIG. 10, the multi-network client device 1000 has the capability to support both CAI Protocol 1 and CAI Protocol 2. While the device is located in public network NTW₁, the multi-network client device 1000 connects to public network NTW₁ utilizing CAI Protocol 1 in a live call session. As the multi-network client device 1000 travels through the public coverage domain area 1001 of public network NTW₁ in FIG. 10, it moves towards the private network NTW₂. In order to maintain the quality of the signal as the device 1000 leaves the current public network NTW₁ and approaches NTW₂, the MSH handoff process begins with the multi-network client device 1000 requesting a heterogeneous handoff from the current wireless network, public network NTW₁ to change the CAI Protocol that is currently being used by the device 1000.

The MSH handoff request transmitted from the multi-network client device 1000 signals to public network NTW₁ that this handoff should be complete in stages. In this exemplary embodiment, the first stage handoffs the multi-network client device 1000 from CAI Protocol 1 within the public coverage domain area 1001 of public network NTW₁ to the multi-protocol private coverage transition domain area 1002 of the private network NTW₂, which is capable of supporting multiple CAI Protocols such as CAI Protocol 1 and CAI Protocol 2. Given this capability, private network NTW₂ is capable of configuring the base stations located within the multi-protocol private coverage transition domain area 1002 to facilitate

a multistage inter-MSC handoff between two networks that support different CAI Protocols.

As generally known, the MSC is responsible for connecting the base station to the network. When a mobile device such as the multi-network client device 1000 moves into a different base station domain while a call is in progress, the MSC automatically transfers the call to a new radio channel belonging to the new base station. According to the present teachings, the base stations, for example, located within the multi-protocol private coverage transition domain area 1002 may be configured to operated on different protocols. In other words, not all base stations connect to the same network may operate on the same protocol. Thus, during the MSH handoff process, when the multi-network client device 1000 enters the multi-protocol private coverage transition domain area 1002 the MSC can transfer the call from a base station operating on CAI Protocol 1 to another base station operation on CAI Protocol 2.

As shown in FIG. 10, the MSH handoff process performs the first stage 104 as a homogeneous inter-MSC handoff when the multi-network client device 1000 cross the boundary area from the public coverage domain area 1001 into the multi-protocol private coverage transition domain area 1002. Once the MSH handoff process completes the homogeneous inter-MSC, the multi-network client device 1000 call sessions is now supported on the private network NTW₂ within the multi-protocol private coverage transition domain area 1002 utilizing CAI Protocol 1, which is the same CAI Protocol 1 that supported the call session within the public coverage domain network 1001 of the public network NTW₁. This stage of the process ensures that all handoff requirements are met for a high quality inter-MSC handoff process.

The MSH handoff process performs the second stage as a heterogeneous inter-Base Station handoff process between two base stations operating on different protocols within the same domain area 1002 on the private network NTW₂. As described above, the multi-protocol private coverage transition domain area 1002 may include base stations operating on different protocols. In this example, the base station in this domain area 1002 may operate on both CAI Protocol 1 and CAI Protocol 2. The heterogeneous inter-MSC handoff process is achieved by allowing the multi-network client device 1000, while hosting an active call session on CAI Protocol 1 through the first base station, to also utilize the multi-protocol processing capability within the SDR access subsystem to set-up a second active call session through the second base station utilizing the CAI Protocol 2. To simultaneously maintain two independent call sessions on the multi-network client device 1000, the new radio parameters are downloaded into the multiple radios (DRPs) of the SDR access subsystem. The multi-network client device 1000 informs the MSC that the two concurrent call sessions are a part of the same call and as such these two call sessions should be bridged together to form a single call session for the multi-network client device 1000.

Once the MSC informs the multi-network client device 1000 that the bridging process has been completed, the multi-network client device 1000 issues a disconnect message to the MSC for the first call session that was established through the first base station supporting CAI Protocol 1, while maintaining the second call session established through the second base station utilizing the second CAI Protocol 2. The disconnection of one of the simultaneous call sessions completes the heterogeneous inter-MSC handoff process. In comparison to conventional handoff methods, the heterogeneous inter-MSC handoff process eliminates the need for any inter-MSC messages to be completed during the second stage of the handoff

process, thereby, ensuring that all handoff requirements are met for a high quality inter-MSC heterogeneous handoff process.

FIG. 11 illustrates an example of execution steps in the MSH handoff process. The method of FIG. 11 starts with the mobile station requiring a handoff during an initial call session and launching the MSH handoff process 1100. In step 1105, the MSC continuously performs a frequency scan process to determine the type of CAI protocols in the surrounding networks and to monitor the signal strengths to determine whether a handoff is required. If so, the process determines what type of handoff is required. The process checks, in step 1110, whether an MSH handoff is required. If no MSH handoff is required, the handoff process returns the controls to the frequency scanning process in step 1105.

If an MSH handoff is required, the process in step 1115 initiates the mobile station CAI scanning process to identify all networks and their corresponding CAIs that are candidates for handoff by this particular mobile station. The mobile station creates a list of handoff candidates to start the MSH handoff process. Once the handoff candidates list is complete, the mobile station compares in step 1120 the list with its internal database to ensure that the mobile station has the CAI capability to complete the MSH handoff process. If the mobile station does not have the CAI capability for the new network, it requests in step 1125 a CAI update through the current network for the new network to send an update of the new CAI protocol parameters.

If the mobile station has the CAI Protocol for the new network in its current database, it loads the parameters into its DRP and starts the homogeneous inter-MSC handoff process in step 1130, which is the first stage of the MSH handoff process. The mobile station continuously checks on the status of the homogeneous inter-MSC handoff process in step 1135 and waits for the completion of the homogeneous inter-MSC handoff process in step 1140. Once the homogeneous inter-MSC handoff process is completed, the mobile station starts the heterogeneous inter-Base station handoff process in step 1145 by downloading the new base station CAI protocol into the mobile station DRP to set the mobile station's radio parameters in the SDR.

After the installation of the CAI protocol into the mobile station's DRP, the mobile station establishes a new call session in step 1150 along parallel talk paths with the same MSC. The mobile station requests the bridging of the two call sessions into a single call session by the MSC in step 1155 for the completion of the MSH handoff process. Once the initial and new call sessions are bridged, the mobile station then requests that the MSC release in step 1160 the initial call session, thereby completing the MSH handoff process in step 1165.

In various embodiments, the multi-network client device has the capability to support multiple simultaneous sessions conducted on a single end user device that connects the device to different networks to receive different sources of content through the use of parallel call sessions maintained by the single end user device. This feature enables the user using a single device, in real time, to be connected to multiple content sources such as, for example, healthcare service providers, information appliances, live content, and other telemetry services. This capability can be accomplished by using multiple DRPs to connect simultaneously to different networks that are concurrently hosting different content services and to simultaneously receive such services.

This feature eliminates the need for such network services such as call waiting where the session is terminated at the local switch and not at the end client device. With today's state of the art, current devices can only connect to one ses-

sion at a time and, when the device needs to switch to a second session, it must communicate with the local switch to change the session. During use of the device to conduct multiple simultaneous communication sessions, in various embodiments, the device is capable of interacting directly with a current network and maintaining an initial communication session while also simultaneously connecting to a new network and establishing a new communication session without having to disconnect from the initial communication session. Either communication session may be used to transmit transmissions such as voice, video, multimedia, data services or any combination thereof.

The invention device enhances the current approach to PRLs by creating a platform for system access through multiple networks regardless of technology. The invention device stores the control channel access methods for different common air interface protocols and applies the proper approach to the indicated network. The invention device's default or preset capability adds enhanced flexibility to accessing the Control Channel by searching according to CAI protocol groups instead of network groups. The technology priority table is defined by order of air interface, for example, GSM followed by IS-136 then cdma2000. Each CAI protocol control channel is accessed in order of priority for a contracted network in which to activate service. The invention takes on this CAI protocol identity and attempts to transmit on a control channel. If the network responds with an acknowledgement, the invention device receives the network's SID information and determines if it is on the invention device's user priority list. Because the invention device can assume different personalities/identities and CAI protocols instantaneously, it can access a control channel in any combination of technology and CAI protocol as required. Current devices are limited by disparate approaches for network access. In older wireless networks such as AMPS and GSM, there is separate traffic and control channel access, versus today's digital wireless networks such as IS-136 which integrate their channel access (traffic and control) to grow capacity. IEEE 802.11x systems have no control channel, and new 3G and 4G networks will likely present yet another approach. The invention operates within any type of network access scheme, now or in the future.

The invention device supports multiple applications in a single unit with no need of user intervention for environment detection and application switching. The invention device automatically detects its environment and presents the corresponding personality to communicate with the available network.

As further explained above, the invention introduces the idea of Position and Protocol Assisted Learning (P²AL), in which the invention device uses its configuration data to gather information about its environment. A menu-driven and user-created Priority Table defines the order in which contracted networks are accessed. With available position data and the network coverage maps it "learned" or "developed" and enhanced over time, the invention device is able to quickly access available contracted networks in the area based on that data. Without that data, the invention device performs a "scan" access based on stored Network Profile and priority information. The P²AL algorithm allows the invention device to "see" its environment, its relationship to that environment, and to more effectively navigate within that environment.

Due to the algorithmic modularity and flexibility of the invention device, the basic architecture of the invention's Position and Protocol Assisted Learning (P²AL) algorithms is adjustable for efficiency and applications. The component

blocks of the P²AL algorithms and flows of interactions are readily mixed, matched and adjusted for innumerable configurations to take advantage of efficiencies, or compensate for inefficiencies, in the invention device's various applications. Such adaptations and flexibility are not possible without the core capabilities which identify this invention device.

The invention device also has the ability to dynamically update its capabilities either via physical means or via download over the air. These updates are originated either by the invention device (user) or originated by the network. With the software defined radio technology and the ability to download new CAI protocols, the invention device provides the ability to access any ad hoc network at any time. This invention truly enables a user to have access to all the subscribed communications services in any location, be it a conference room, remote location, airport or other transition point, at any time. This greatly enhances the user's efficiency and productivity.

This invention device eliminates the need for having external technology or service constructs to simulate contiguous service such as SIM cards (or other personality cards).

In addition to supporting conventional subscription-based services and transaction-based services (e.g., pre-paid services, calling card services), the invention device also introduces a mechanism for real-time transaction-based services, where there is a one-time transaction fee for a higher level of service access. With real-time transaction-based services, the user can make a one-time arrangement with the network for temporary usage of services through a unique encrypted billing number stored within it.

The invention provides a platform for enhanced business services such as call waiting, call forwarding, conference calling, Centrex-like services, data, video, and multimedia services with true mobility within a wireless communications environment. The invention device also provides a platform for Virtual Private Network (VPN) support.

The invention device also provides a platform for incorporating advanced wireless network architecture and design. The learning techniques and location awareness of the invention device provides a means for further exploitation with an enhanced network architecture and service platform to create an advanced network capability.

The flexibility of this database structure and the algorithms themselves support a myriad of implementations using the fundamental structure to efficiently execute the invention device's functionality.

Current networks limit the user devices to either subscription-based services with permanent databases and account control or transaction-based services such as pre-paid services. This invention redefines the method for "roaming". Conventionally, subscription-based services benefit the user most in their home environment. Outside that home environment, the user accrues a higher rate of billing for limited access in a roaming environment. With multiple personality capability, the frequently visited environments become additional "home" environments to the user with all the "home" environment advantages. For less frequently visited environments, the invention device allows the user to enjoy services based on transaction-based service arrangements. The invention device also introduces a mechanism for real-time transaction-based services, where there is a one-time transaction fee for a higher level of service access. With real-time transaction-based services, the user can make a one-time arrangement with the network for temporary usage of services. The invention device uses a unique encrypted billing number stored within it. This billing authentication code requires the use of a special PIN (Personal Identification Number) and codeword combination by the user to unlock the billing code.

This pre-set number is associated by the user with a billing number/account such as a credit card number, which allows the invention device to be used for transaction-based services. In this transaction processing, the PIN and codeword combination also unlocks the encrypted information in the user identity profile database transmitting the user specific network requirements to the service activation network, including the invention device's portable number (e.g. wireless personal number).

The invention device provides a mechanism for an enhanced network to provide flexibility and expanded capability. It also provides tiered levels of security for access to business line networks such as VPNs through the use of the invention devices' User Personality Profile (UPP) configuration database.

This invention defines the architecture and design of a device that greatly expands the capability of current wireless devices to support multiple networks with the ease and advantage of a "home" device appearance. The invention device is used as a "home" device to access multiple registered networks.

Thus, in summary, in visualizing the use of device **10**, FIG. **1** layers several networks upon themselves to show the device's process within them as described above. Device **10** uses its GPS system data as well as its coverage maps and network profiles to create an accurate map of its location. The GPS information is gathered to create locational boundaries. Network information is the reference point for creating that boundary information. The invention device functions as a sensor to gather intelligence about the boundaries of the different networks it travels into. This sensing function allows the invention device to see the networks when they stack together and to create a map of the coverage. All of the network profile information that goes along with any GPS system data is collected and related.

While the invention device may exist geographically in multiple contracted networks, it will register in those networks according to its P²AL algorithm. Starting with its highest priority contracted network (which could be its Home Network in an enhanced network environment), it passes into another contracted network which it recognizes by the Network Coverage Map (or the SID) and after communication acknowledgement with the network, provides the associated User Personality Profile information to the wireless network for service activation. As it passes into a non-contracted network (WN), known to be non-contracted because none of the stored profiles matches it, the invention device uses transaction-based billing to function as a visitor, or in an enhanced network architecture, provides a platform for storing temporary Network Profile data and having its home network assign a temporary User Personality Profile (UPP) for the transaction. Passing once again into another contracted network, recognized by its Network Profile (or SID), after communication acknowledgement with the network, the invention device **10** provides the corresponding user profile data for service activation.

The invention device provides a modular, expandable, platform for sensing and navigating effectively through its environment with programmable access capabilities. The invention provides seamless network access across multiple networks in any CAI protocol without requiring a home network to anchor its identity. The invention device functions as a transaction device for alternative billing in networks with which it is not contracted. Finally, the invention provides a future-proofed platform for enhanced wireless network constructs enabling its use in next generation wireless communications networks.

While there have been shown and described and pointed out fundamental novel features of the invention as applied to preferred embodiments thereof, it will be understood that various omissions and substitutions and changes in the form and details of the devices illustrated, and in their operation, 5 may be made by those skilled in the art without departing from the spirit of the invention. For example, it is expressly intended that all combinations of those elements which perform substantially the same function in substantially the same way to achieve the same results are within the scope of the invention. It is the intention, therefore, to be limited only as indicated by the scope of the claims appended hereto. 10

What is claimed is:

1. A method for automatically adapting a multi-protocol wireless device to facilitate a seamless multistage handoff, the method comprising: 15

(a) generating a seamless multistage handoff request initiated by a multi-protocol wireless device when the multi-protocol wireless device crosses a boundary area into an overlapping region where the multi-protocol wireless device is capable of simultaneously accessing a plurality of networks; 20

(b) providing the multi-protocol wireless device comprising: 25

a single transceiver configured to transmit a request and receive a download to store at least one program into a plurality of Digital Radio Platforms (DRPs) to configure a plurality of Software Define Radios (SDRs), respectively, to store multiple transmission technologies to establish communication simultaneously with a plurality of networks; 30

a memory for storing data and instructions in at least one database, wherein the at least one database is configured to store network profiles for the plurality of networks to enable the multi-protocol wireless device to simultaneously communicate with the plurality of networks; 35

a processor having software modules configured to access the memory and when executing the instructions to perform the steps of: 40

(i) monitoring a radio channel of a local unknown network to detect data transmitted in an unknown communication protocol from the local unknown network; 45

(ii) receiving the data transmitted in the unknown communication protocol via the radio channel from the local unknown network;

(iii) analyzing the data transmitted in the unknown communication protocol to decipher the unknown communication protocol to obtain and store in the software modules a learning data to learn a communication format for the unknown communication protocol; and 50

(iv) using the learned communication format in the software modules of the processor to dynamically match data of the request transmitted from the transceiver with data of the unknown communication protocol to establish the communication with the plurality of networks, including the local unknown network and to adapt the multi-protocol wireless device to implement the seamless multistage handoff process by performing at least a two-stage handoff process comprising a homogeneous handoff and a heterogeneous handoff without interrupting a communication call session conducted using the multi-protocol wireless device; 65

(c) performing the homogeneous handoff between a first network operating on a first communication protocol and a second network operating on a second communication protocol, wherein the first network is an existing network in use by the multi-protocol wireless device at a time of crossing the boundary area and the first communication protocol and the second communication protocol having compatible transmission technologies, and the first network and the second network are different networks of the plurality of networks; and

(d) performing the heterogeneous handoff within the second network between the second protocol and a third communication protocol, wherein the second communication protocol and the third communication protocol having incompatible transmission technologies. 20

2. The method of claim **1**, wherein the compatible transmission technologies having compatible Common Air Interface (CAI) protocol parameters and the incompatible transmission technologies having incompatible CAI protocol parameters. 25

3. The method of claim **1**, wherein performing the homogeneous handoff in step (c) and performing the heterogeneous handoff in step (d) further comprises: 30

(e) requesting using the multi-protocol wireless device a download of at least a second transmission technology to configure at least one of the plurality of Software Define Radios (SDRs), wherein the transmission technology of the first network is stored as a first transmission technology in one of the plurality of SDRs when the multi-protocol wireless device crosses the boundary area. 35

4. The method of claim **3**, wherein the step of (e) further comprises: 40

(f) downloading and simultaneously storing multiple transmission technologies to configure respective SDRs for each transmission technology to establish multiple simultaneous communication sessions with each of the plurality of networks. 45

5. The method of claim **4**, wherein the multi-protocol wireless device comprises a plurality of Digital Radio Processing platforms for supporting a transmission in each transmission technology. 50

6. The method of claim **5**, wherein the transmission technology comprises a technology selected from a group consisting of CDMA, TDMA, CSMA, OFDA, GSM, cdma2000, IS-136, IEEE 802.11x, IEEE 802.16x, a protocol supporting High Speed Internet Access, a protocol supporting a transmission of Video data, a protocol supporting the transmission of audio data, and a protocol supporting a transmission of multimedia data. 55

7. The method of claim **1**, further comprising: performing the homogeneous handoff followed by the heterogeneous handoff to establish two simultaneous parallel communication sessions. 60

8. The method of claim **1**, further comprising: utilizing the homogeneous handoff to establish the heterogeneous handoff and two simultaneous parallel communication sessions. 65

9. The method of claim **7**, further comprising: terminating the homogeneous handoff and one of the two communication sessions after establishing the heterogeneous handoff.

10. The method of claim **8**, further comprising: terminating the homogeneous handoff and one of the two communication sessions after establishing the heterogeneous handoff.

11. The method of claim 7, wherein at least one of the plurality of networks is selected from contracted networks, non-contracted networks, private networks, and public networks.

12. The method of claim 7, wherein at least one of plurality of networks is one of a wide area wireless network, an in-building wireless network, a campus wireless network, or an enterprise network.

13. The method of claim 8, wherein at least one of the plurality of networks comprises networks selected from contracted networks, non-contracted networks, private networks, and public networks.

14. The method of claim 8, wherein at least one of the plurality of networks is one of a wide area wireless network, an in-building wireless network, a campus wireless network, or an enterprise network.

15. The method of claim 1, further comprising:
performing the heterogeneous handoff followed by the homogeneous handoff to establish two simultaneous parallel communication sessions.

16. The method of claim 15, further comprising:
terminating the heterogeneous handoff and one of the two communication sessions after establishing the homogeneous handoff.

17. The method of claim 15, wherein at least one of the plurality of networks is selected from contracted networks, non-contracted networks, private networks, and public networks.

18. The method of claim 15, wherein at least one of the plurality of networks is one of a wide area wireless network, an in-building wireless network, a campus wireless network, or an enterprise network.

19. The method of claim 1, further comprising:
utilizing the heterogeneous handoff to establish the homogeneous handoff and two simultaneous parallel communication sessions.

20. The method of claim 19, further comprising:
terminating the heterogeneous handoff and one of the two communication sessions after establishing the homogeneous handoff.

21. The method of claim 19, wherein at least one of the plurality of networks comprises networks selected from contracted networks, non-contracted networks, private networks, and public networks.

22. The method of claim 19, wherein at least one of the plurality of networks is one of a wide area wireless network, an in-building wireless network, a campus wireless network, or an enterprise network.

23. The method of claim 1, further comprising implementing the multistage handoff using an update algorithm.

24. A multi-protocol wireless device automatically adaptable to facilitate a multistage handoff, the multi-protocol wireless device comprising:

a single transceiver configured to transmit a request and receive a download to store at least one program into a plurality of Digital Radio Platforms (DRPs) to configure a plurality of Software Define Radios (SDRs), respectively, to store multiple transmission technologies to establish communication simultaneously with a plurality of networks;

a memory for storing data and instructions in at least one database, wherein the at least one database is configured to store network profiles for the plurality of networks to enable the multi-protocol wireless device to simultaneously communicate with the plurality of networks;

a processor having software modules configured to access the memory and when executing the instructions to perform the steps of:

(a) monitoring a radio channel of a local unknown network to detect data transmissions in an unknown communication protocol from the local unknown network;

(b) receiving the data transmitted in the unknown communication protocol via the radio channel from the local unknown network;

(c) analyzing the data transmitted in the unknown communication protocol to decipher the unknown communication protocol to obtain and store in the software modules a learning data to learn a communication format for the unknown communication protocol;

(d) using the learned communication format in the software modules of the processor to dynamically match data of the request transmitted from the transceiver with data of the communication protocol to establish communication with the local unknown network such that the simultaneous communication with the plurality of network includes communication with the local unknown network and to adapt the multi-protocol wireless device to initiate a multistage handoff algorithm using the multi-protocol wireless device and the at least one database provides a means to configure a multistage handoff algorithm to select at least one wireless network of the plurality of networks to communicate with when the multi-protocol wireless device crosses a boundary area into an overlapping region where the multi-protocol wireless device is capable of simultaneously accessing the plurality of networks;

the multistage handoff algorithm comprises at least a homogeneous handoff algorithm configured to execute a homogeneous handoff and a heterogeneous handoff algorithm configured to execute a heterogeneous handoff, wherein the multistage handoff algorithm executes the homogeneous handoff and heterogeneous handoff without interrupting a communication call session conducted using the multi-protocol wireless device;

the processor instructs the homogeneous handoff algorithm to execute the homogeneous handoff between a first network operating on a first communication protocol and a second network operating on a second communication protocol when the multi-protocol wireless device crosses the boundary area, wherein the first network is an existing network in use by the multi-protocol wireless device at a time of crossing the boundary area and the first communication protocol and the second communication protocol having compatible transmission technologies, and the first network and the second network are different networks of the plurality of networks; and

the processor instructs the heterogeneous handoff algorithm to execute the heterogeneous handoff within the second protocol and a third communication protocol, wherein the second communication protocol and the third communication protocol having incompatible transmission technologies.

25. The device of claim 24, wherein the at least one program includes at least one CAI protocol image.

26. The device of claim 24, wherein the compatible transmission technologies having compatible Common Air Interface (CAI) protocol parameters and the incompatible transmission technologies having incompatible CAI protocol parameters.

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27. The device of claim 24, wherein the multi-protocol wireless device requests the download of at least a second transmission technology to configure at least one of the SDRs, wherein the transmission technology of the first network is stored as a first transmission technology in one of the plurality of SDRs when the multi-protocol wireless device crosses the boundary area.

28. The device of claim 24, wherein the at least one transceiver downloads and the DRPs simultaneously store multiple transmission technologies to configure respective SDRs for each transmission technology to establish multiple simultaneous communication sessions with each of the plurality of networks.

29. The device of claim 28, wherein the transmission technology comprises a technology selected from a group consisting of CDMA, TDMA, CSMA, OFDA, GSM, cdma2000, IS-136, IEEE 802.11x, IEEE 802.16x, a protocol supporting High Speed Internet Access, a protocol supporting a transmission of Video data, a protocol supporting a transmission of audio data, and a protocol supporting a transmission of multimedia data.

30. The device of claim 24, wherein the processor instructs the homogeneous handoff algorithm to execute the homogeneous handoff then instructs the heterogeneous handoff algorithm to execute the heterogeneous handoff to establish two simultaneous parallel communication sessions.

31. The device of claim 30, wherein the processor instructs the homogeneous handoff algorithm to terminate the homogeneous handoff and one of the two communication sessions after establishing the heterogeneous handoff.

32. The device of claim 30, wherein at least one of the plurality of networks comprises networks selected from contracted networks, non-contracted networks, private networks, and public networks.

33. The device of claim 30, wherein at least one of the plurality of networks is one of a wide area wireless network, an in-building wireless network, a campus wireless network, or an enterprise network.

34. The device of claim 24, wherein the processor instructs the heterogeneous handoff algorithm to execute the heterogeneous handoff then instructs the homogeneous handoff algorithm to execute the homogeneous handoff to establish two simultaneous parallel communication sessions.

35. The device of claim 34, wherein the processor instructs the heterogeneous handoff algorithm to terminate the heterogeneous handoff and one of the two communication sessions after establishing the homogeneous handoff.

36. The device of claim 34, wherein at least one of the plurality of networks comprises networks selected from contracted networks, non-contracted networks, private networks, and public networks.

37. The device of claim 34, wherein at least one of the plurality of networks is one of a wide area wireless network, an in-building wireless network, a campus wireless network, or an enterprise network.

38. A method for automatically adapting a multi-protocol wireless device to facilitate a seamless multistage handoff, the method comprising:

- (a) generating a seamless multistage handoff request initiated by a multi-protocol wireless device when the multi-protocol wireless device crosses a boundary area into an overlapping region where the multi-protocol wireless device is capable of simultaneously accessing a plurality of networks; and
- (b) providing the multi-protocol wireless device comprising:

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a single transceiver configured to transmit a request and receive a download to store at least one program into a plurality of Digital Radio Platforms (DRPs) to configure a plurality of Software Define Radios (SDRs), respectively, to store multiple transmission technologies to establish communication simultaneously with a plurality of networks;

a memory for storing data and instructions in at least one database, wherein the at least one database is configured to store network profiles for the plurality of networks to enable the multi-protocol wireless device to simultaneously communicate with the plurality of networks;

a processor having software modules configured to access the memory and when executing the instructions to perform the steps of:

- (i) monitoring a radio channel of a local unknown network to detect data transmitted in an unknown communication protocol from the local unknown network;
- (ii) receiving the data transmitted in the unknown communication protocol via the radio channel from the local unknown network;
- (iii) analyzing the data transmitted in the unknown communication protocol to decipher the unknown communication protocol to obtain and store in the software modules a learning data to learn a communication format for the unknown communication protocol; and
- (iv) using the learned communication format in the software modules of the processor to dynamically match data of the request transmitted from the transceiver with data of the unknown communication protocol to establish the communication with the plurality of networks, including the local unknown network and to adapt the multi-protocol wireless device to implement the seamless multistage handoff process by performing at least a two-stage handoff process comprising a homogeneous handoff and a heterogeneous handoff without interrupting a communication call session conducted using the multi-protocol wireless device.

39. The method of claim 38, further comprising: performing the homogeneous handoff followed by the heterogeneous handoff to establish two simultaneous parallel communication sessions.

40. The method of claim 39, further comprising: terminating the homogeneous handoff after establishing the heterogeneous handoff.

41. The method of claim 38, further comprising: performing the heterogeneous handoff followed by the homogeneous handoff to establish two simultaneous parallel communication sessions.

42. The method of claim 41, further comprising: terminating the heterogeneous handoff after establishing the homogeneous handoff.

43. A method for automatically adapting a multi-protocol wireless device to facilitate a seamless multistage handoff, the method comprising:

- (a) generating a seamless multistage handoff request initiated by a multi-protocol wireless device when the multi-protocol wireless device crosses a boundary area into an overlapping region where the multi-protocol wireless device is capable of simultaneously accessing a plurality of networks by establishing multiple simultaneous parallel communication sessions; and

- (b) providing the multi-protocol wireless device comprising:
- a single transceiver configured to transmit a request and receive a download to store at least one program into a plurality of Digital Radio Platforms (DRPs) to configure a plurality of Software Define Radios (SDRs), respectively, to store multiple transmission technologies to establish communication simultaneously with a plurality of networks;
 - a memory for storing data and instructions in at least one database, wherein the at least one database is configured to store network profiles for the plurality of networks to enable the multi-protocol wireless device to simultaneously communicate with the plurality of networks;
 - a processor having software modules configured to access the memory and when executing the instructions to perform the steps of:
 - (i) monitoring a radio channel of a local unknown network to detect data transmitted in an unknown communication protocol from the local unknown network;
 - (ii) receiving the data transmitted in the unknown communication protocol via the radio channel from the local unknown network;
 - (iii) analyzing the data transmitted in the unknown communication protocol to decipher the unknown communication protocol to obtain and store in the software modules a learning data to learn a communication format for the unknown communication protocol; and
 - (iv) using the learned communication format in the software modules of the processor to dynamically match data of the request transmitted from the transceiver with data of the unknown communication protocol to establish the communication with the plurality of networks, including the local unknown network and to adapt the multi-protocol wireless device to implement the seamless multi-stage handoff process by performing at least a two-stage handoff process comprising a homogeneous handoff and a heterogeneous handoff without interrupting an initial communication call session conducted using the multi-protocol wireless device.
- 44.** A multi-network client device comprising:
- a controller configured to support multiple independent call sessions, wherein the independent call sessions are concurrently conducted on a single wireless device through the use of parallel communication sessions and simultaneously connect the wireless device to a plurality of different networks hosting different content services; the controller connects to and controls a single transceiver included in the wireless device;
 - the wireless device comprises:
 - the single transceiver is configured to transmit a request and receive a download to store at least one program into a plurality of Digital Radio Platforms (DRPs) to configure a plurality of Software Define Radios (SDRs), respectively, to store multiple transmission technologies to establish the parallel communication sessions simultaneously with the plurality of different networks hosting the different content services;
 - a memory for storing data and instructions in at least one database, wherein the at least one database is configured to store network profiles for the plurality of networks to enable the wireless device to simultaneously communicate with the plurality of different networks;

- a processor having software modules configured to access the memory and when executing the instructions to perform the steps of:
 - (i) monitoring a radio channel of a local unknown network to detect data transmitted in an unknown communication protocol from the local unknown network;
 - (ii) receiving the data transmitted in the unknown communication protocol via the radio channel from the local unknown network;
 - (iii) analyzing the data transmitted in the unknown communication protocol to decipher the unknown communication protocol to obtain and store in the software modules a learning data to learn a communication format for the unknown communication protocol; and
 - (iv) using the learned communication format in the software modules of the processor to dynamically match data of the request transmitted from the transceiver with data of the unknown communication protocol to establish the parallel communication sessions with the plurality of different networks, including the local unknown network.
- 45.** The multi-network client device of claim **44**, wherein at least one of the parallel communication sessions transmits at least one transmission of voice, video, multimedia and data services.
- 46.** A method of conducting multiple simultaneous call sessions, the method comprising:
- conducting independent call sessions concurrently on a single wireless device using parallel communication sessions;
 - simultaneously connecting the wireless device to a plurality of different networks hosting different content services; and
 - providing the wireless device comprising:
 - a single transceiver configured to transmit a request and receive a download to store at least one program into a plurality of Digital Radio Platforms (DRPs) to configure a plurality of Software Define Radios (SDRs), respectively, to store multiple transmission technologies to establish the parallel communication sessions simultaneously with the plurality of different networks hosting the different content services;
 - a memory for storing data and instructions in at least one database, wherein the at least one database is configured to store network profiles for the plurality of networks to enable the wireless device to simultaneously communicate with the plurality of different networks;
 - a processor having software modules configured to access the memory and when executing the instructions to perform the steps of:
 - (i) monitoring a radio channel of a local unknown network to detect data transmitted in an unknown communication protocol from the local unknown network;
 - (ii) receiving the data transmitted in the unknown communication protocol via the radio channel from the local unknown network;
 - (iii) analyzing the data transmitted in the unknown communication protocol to decipher the unknown communication protocol to obtain and store in the software modules a learning data to learn a communication format for the unknown communication protocol; and
 - (iv) using the learned communication format in the software modules of the processor to dynamically

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match data of the request transmitted from the transceiver with data of the unknown communication protocol to establish the parallel communication sessions with the plurality of different networks, including the local unknown network.

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47. The method of claim **46**, wherein at least one of the parallel communication sessions transmits at least one transmission of voice, video, multimedia and data services.

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